

Section 319
Perry County Karst Watershed
Nonpoint Source
Management Plan

Prepared by the
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Perry County Karst Watershed Management Plan

Mission Statement

Protecting our fish, by protecting our water



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Acronyms

Acronym	Name
ANS	Aquatic Nuisance Species
AQL	Aquatic Life Protection
BMP	Best Management Practices
CAFO	Confined Animal Feeding Operation
CLF	Cool Water Fishery
Cl ⁻	Chloride
COA	Conservation Opportunity Area
CoCoRaHS	Community Collaborative Rain, Hail, and Snow Network
CCRP	Continuous Conservation Reserve Program
CRP	Conservation Reserve Program
CSR	Missouri Code of State Regulations
DWS	Drinking Water Source
EPA	Environmental Protection Agency
ESA	Endangered Species Act
EQIP	Environmental Quality Incentives Program
FSA	Farm Services Agency
GEN	General Protection
GIS	Global Information System
GRW	Groundwater
HPP	Human Health Protection

IRR	Industrial Irrigation
LAP	Landowner Assistance Program
LWW	Livestock and Wildlife Watering
MSS/CRF	Missouri Speleological Survey Cave Research Foundation
MCKC	Missouri Caves and Karst Conservancy
MDC	Missouri Department of Conservation
MoDNR	Missouri Department of Natural Resources
MUExt	University of Missouri Extension Center
NH ₃ -N	Ammonia as Nitrogen
NGO	Non-Government Organization
NO ₂ ⁻ -N	Nitrite as Nitrogen
NO ₃ ⁻ -N	Nitrate as Nitrogen
NPR	National Public Radio
NPS	Nonpoint Source Pollutant
NPS-WMP	Nonpoint Source Watershed Management Plan
NRCS	Natural Resources Conservation Service
PCCEEC	Perry County Community Economic and Environment Committee
PCFB	Perry County Farm Bureau
PCHD	Perry County Health Department
PCK	Perry County Karst
PCSWCD	Perry County Soil and Water Conservation District
POCIS	Polar Organic Chemical Integrative Samplers
PO ₄ ³⁻ -P	Ortho-Phosphate
RCPP	Regional Conservation Partnership Program
SEMO	Southeast Missouri State University
SCR	Secondary Contact Recreation
SPMD	Semipermeable Membrane Devices
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
WBC A/B	Whole Body Contact Recreation
WHIP	Wildlife Habitat Incentive Program
WRP	Wetland Reserve Program

Executive Summary

The Perry County Soil and Water Conservation District (PCSWCD) received a federal grant to fund the preparation of a Perry County Karst (PCK) Watershed Management Plan for the Perry County portion of the Perryville Karst Region. The watershed management plan is the culmination of four and a half years of water quality habitat monitoring, recharge delineations (area of land that drains into a subsurface watershed), and public education. The PCSWCD and the Missouri Department of Conservation (MDC) worked closely with local, state, and federal stakeholders, while maintaining economic vitality and respecting community values, to identify water quality impairments and restoration opportunities, as well as protecting sensitive wildlife habitat in both the surface and subsurface watersheds.

The PCK project area encompasses approximately 145,893 acres in the eastern half of Perry County in Southeast Missouri. The Perry County karst has over 680 known caves, the most of any county in Missouri.

This plan is intended to fulfill the nine part element criteria required by the Environmental Protection Agency (EPA) and the Missouri Department of Natural Resources (MoDNR) in support of a 319 grant funding application. The two agencies used the data collected in the 319 mini-grant to assess the watersheds and to help generate this watershed management plan. The plan is designed to focus the efforts of private, city, county, state, and federal stakeholders on protecting surface water and groundwater health in the PCK watersheds; as, the county continues to urbanize and increase agricultural production. The PCK watershed management plan provides recommendations that, if adopted, will achieve specific goals that enhance the PCK watersheds through attainment of Missouri's Water Quality Standards.

Plan Summary

This plan was created to address water quality impairments and other water quality concerns within the PCK watershed. MoDNR has identified several streams in Perry County as impaired due to high concentrations of *E. coli* bacteria. Additionally, this plan addresses excessive sediment and nutrient loading to these streams, which are having negative implications for aquatic communities. This plan is considered a living document and currently addresses the impairments and water quality issues identified during the EPA 319 mini-grant (G04-NPS-27) and subgrant (G07-NPS-03) conducted by MDC and PCSWCD. A detailed analysis of the EPA 319 mini-grant and subgrant administered by MoDNR can be reviewed in Section 4. The following are the goals and objectives for addressing and reducing impairments within the PCK watershed.

GOAL 1. Attain Water Quality Standards throughout the Perry County Karst watershed.

Objective 1: Monitor water quality by continuous logging and monthly grab samples to identify trends within the designated range of Grotto Sculpin (*Cottus specus*).

Objective 2: Reduce sediment and nutrient loading into surface waters by increasing vegetative buffers, riparian corridors or other acceptable best management practices (BMPs) in defined critical areas near streams, sinkholes, springs, and vertical drainpipes in PCK.

Objective 3: Reduce *E. coli* levels to concentrations that achieve applicable recreational uses in accordance with Missouri's Water Quality Standards rules in the Code of State Regulations (CSR) at 10 CSR 20-7.031.

Objective 4: Reduce nonpoint source nutrients, chemicals, and other hazardous materials from entering the PCK groundwater.

GOAL 2. Monitor the abundance and distribution of the Grotto Sculpin population; while, documenting karst biodiversity in the surface and subsurface streams within the Perry County Karst watershed.

Objective 1: Monitor Grotto Sculpin population trends across their range within the PCK watershed.

Objective 2: Monitor aquatic macroinvertebrates in PCK watershed as these are good indicators of water quality.

Objective 3: Inventory and monitor cave life throughout PCK focusing on areas where Grotto Sculpin reside.

GOAL 3. Provide technical assistance and improve Perry County Karst stakeholder awareness about groundwater movement and sources of pollutants impacting the Perry County Karst Watershed.

Objective 1: Engage both urban and rural residents within the PCK through various media outlets promoting the management and protection of karst and surface water resources.

Objective 2: Provide pertinent forums for community outreach and education to be discussed regarding PCK management, protection, and progress.

Section 1. INTRODUCTION

The Perryville Karst is one of several karst zoogeographic regions in Missouri. These regions include the Springfield and Salem plateaus, the Boone, Hannibal, St. Louis, Jefferson-Ste. Genevieve, and Perryville Karst, and an isolated Caney Mountain area (Elliott 2007; Figure 1.1). The Perryville Karst encompasses most of the eastern portion of Perry County, Missouri. Perry County leads the state in the number of known caves at more than 680, and it also boasts some of the longest caves, e.g. Crevice Cave (45 km), Moore Cave System (29 km), Mystery Cave (25.5 km), and Rimstone River Cave (22.8 km).

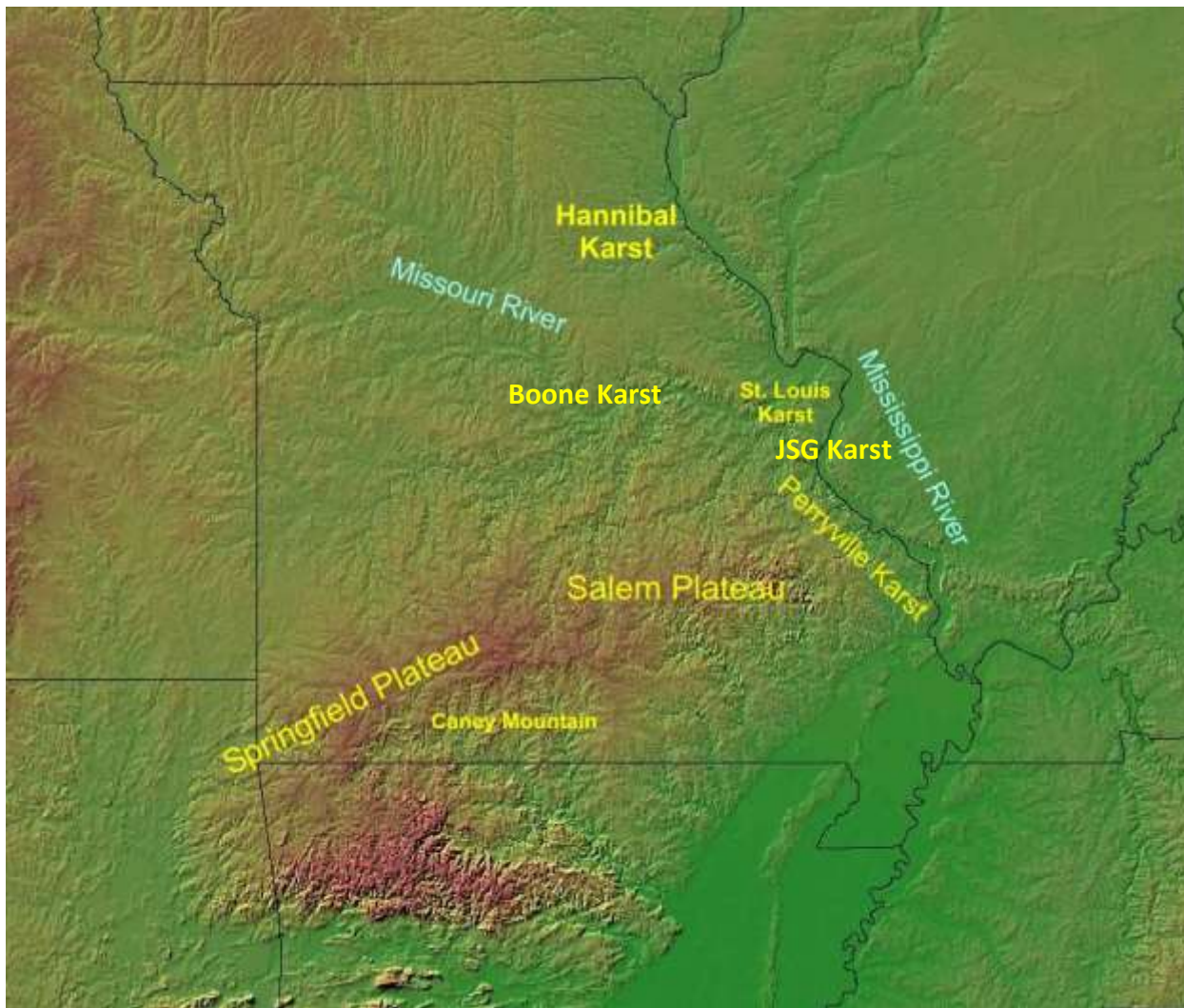


Figure 1.1 Map of karst zoogeographic regions in Missouri. Note JSG represents the Jefferson-Ste. Genevieve Karst.

A nonpoint source pollutant (NPS) is defined by MoDNR as untreated pollution that cannot be traced to any single source within a watershed. A NPS generally enters waterways as runoff from overland flows associated with multiple sources (i.e., rain events, snowmelt, agricultural practices, land disturbances) which picks up and transports nutrients, sediments, pathogens, and chemical

constituents causing water impairments. Because of the karst features, the development of the nonpoint source watershed management plan will provide guidance to not only protect and restore surface waters, but also the unique cave and sinkhole habitats found in this combination of watersheds. This area contains thousands of sinkholes ranging from a few meters to several hundred meters in diameter. Educating stakeholders and providing incentives to manage these sinkholes for the benefit of landowners can improve wildlife, water quality, and the quality of life for everyone.

The Perry County Karst Watershed Plan will also provide guidance for the management and protection of the unique populations of the Grotto Sculpin (*Cottus specus*) that are found within the watershed. This species is endemic to the five major cave systems in the Perryville Karst. These troglomorphic fish are state-threatened and have been designated as endangered under the Endangered Species Act (ESA). Due to the unstable nature of the cave environment, Grotto Sculpins are highly susceptible to pollution via agricultural and urban runoff.

This plan will also provide guidance for the management and protection of water resources within this ecoregion. Water quality studies over the past years have indicated that water-borne contaminants can move very quickly through the groundwater system in this watershed. Contamination can come from both direct and indirect sources. This plan will provide a framework that will help with understanding the issues and concerns within the watershed and will provide an understanding of what is needed to maintain and improve water quality. Findings from previous studies (see Section 4 for a detailed explanation of water quality results) showed nitrate, total phosphorus, atrazine, and *E. coli* were frequently outside of the expected ranges at several locations when compared to EPA regional guidance. Sites were grouped and reported by HUC 12 watersheds. Data was investigated across seasons to determine when the elevated values were occurring. Seasonal evaluations were completed to data collected during the spring (April – June), summer (July – September), fall (October – December) and winter (January – March).

1.1 Watershed Management Plan Purpose

The purpose of the nonpoint source watershed management plan (NPS-WMP) for the PCK watershed is to create local strategies to achieve two water resource goals: 1) restoring streams to state water quality standards; and, 2) promoting wise-watershed stewardship practices throughout the PCK watershed planning area to reduce all sources of nonpoint source pollutants. This NPS-WMP provides assessment and management information, including actions, participants and resources needed for NPS-WMP implementation. The NPS-WMP identifies sources contributing to nonpoint source pollutants, identifies and prioritizes critical areas, and recommends specific management measures necessary to achieve water resource goals.

1.2.1 Watershed Management Team

A watershed management team is a group of stakeholders from various backgrounds and interests, working together to pursue a common goal. In 2005, a group of individuals from cooperating agencies and local landowners decided to pursue a Clean Water Act, section 319 grant, to protect the groundwater and streams from nonpoint source pollution. The overall goal of the project was to use watershed planning to protect the groundwater and streams as well as the habitats of unique species

within the karst region. After being awarded the grant, the group formed a Steering Committee in 2006 (see Appendix A for the membership). Members represented local, state and federal governmental agencies. They provided input and assistance in facilitating the development of the land-use plan, educating the public, and promoting the project to county residents and in the local media. Select staff of the PCSWCD and MDC directed the work of the project. In 2012, a second committee was formed called the Perry County Community Economic and Environment Committee (PCCEEC) which formulated a community plan to address the proposed listing of Grotto Sculpin as endangered by the US Fish and Wildlife Service (USFWS; see Appendix B for the membership). This group developed a community plan with technical assistance from the USFWS, MDC, PCSWCD, and University of Missouri Extension Center (MUExt) to address past, current, and future management goals for improving the PCK watershed (see <http://extension.missouri.edu/perry> for draft community plan). This watershed management plan is being developed to satisfy the EPA nine element criteria, for consideration of 319 grant funding. The goals, objectives, and strategies stated in Section 5, will be used to guide all stakeholders involved to address the current water quality impairments and concerns in this watershed.

1.2.2 Public Participation

The first meeting to discuss issues and concerns in the Perryville Karst Region was in January 2005. At this meeting 16 individuals from MDC, Natural Resources Conservation Service (NRCS), PCSWCD, Perry County Health Department (PCHD), Southeast Missouri State University (SEMO), and the University of Central Arkansas discussed issues and concerns in the Perryville Karst. From this meeting a list of goals was listed to pursue if funding became available. This included:

- Recharge delineation for each of the cave systems.
- Awareness through outreach and education.
- Landowner incentive programs.
- Baseline water quality data.
- Sinkhole cleanout program.

After the initial meeting, a committee of landowners met with federal, state and county officials to discuss issues in the Perryville Karst (see Appendix A for the membership). This committee met several times between February 2005 and June 2006. The committee's goal was to analyze and recommend solutions for problems in the Perryville Karst Region. The following issues were identified and prioritized:

- Current water quality data indicates the presence of nutrient and bacterial contamination in the shallow ground water that flows through several cave systems.
- Potential for Grotto Sculpin population declines.
- Present and predicted urbanization increasing runoff contamination.
- Sinkhole erosion.
- Septic system failures.

After reviewing all of the available information, the Committee recommended the following actions:

- Detailed recharge delineations should be conducted to determine the recharge area of each major cave system in the Perryville Karst Region. This would include determining potential contaminant sources in the recharge areas.
- Develop a long term water quality monitoring program for four cave systems that are known to contain the Grotto Sculpin.
- Determine the population size and genetic profile of the Grotto Sculpin.
- Assess Cinque Hommes Creek using nitrate, nitrite, dissolved oxygen, pH, ortho-phosphate, organophosphate pesticides, and atrazine as indicators.
- Develop an educational program to increase public awareness regarding water quality and assist local landowners in the selection of agricultural BMPs to protect their water resources and the natural habitat of the Grotto Sculpin.
- Determine the best way to clean-up trash laden sinkholes.

To provide information and educate the local citizenry about the unique environment they live in, several public forums and workshops were held. Participants were asked to provide information regarding their knowledge of the karst systems and what issues or concerns they perceived. Forums and workshops included:

- Landowner Meeting – Perryville Karst Overview, Perryville. April 2005, 12 people in attendance.
- Dr. Ginny Adams, University of Central Arkansas – Presentation on Grotto Sculpin and their Habitat in the Caves of the Perryville Karst, Perry County Soil and Water Conservation District Annual Meeting, March 2006, Approximately 230+ people in attendance.
- Missouri Department of Conservation produced a video on the Perryville Karst called “Cave Sculpin” through their Missouri Outdoor Program in 2006. This video has been and will be used in presentations on the Perryville Karst. The video can be viewed at: <http://mdc4.mdc.mo.gov/tv/video.asp?mediaID=ae253680c9fb1dbb661175692b51cc07>
- Landowner Meeting – Perryville Karst 319 Grant Overview, Perry County Soil and Water Conservation District Annual Meeting, March 2007, Approximately 230+ people in attendance.
- Landowner/Homeowner Meeting on the Perryville Karst was held in Perryville on 15th May 2007, 8 citizens attended. Water quality and karst publications were distributed to those attending.
- Landowner/Homeowner Meeting on the Perryville Karst was held in Perryville on 15th August 2007, 10 citizens attended. Water quality and karst publications were distributed to those attending.
- Local news station produced a segment on Grotto Sculpin and the Perryville Karst that was aired in October 2007.
- Landowner Meeting – Perryville Karst Issues and Concerns, Perry County Soil and Water Conservation District Annual Meeting, March 2008, Approximately 200 people in attendance.
- Informational Booth on Perryville Karst, Ecological History Day Conservation Nature Center in Cape Girardeau, June 2008.
- Perry County Soil and Water Conservation District and MDC – Informational Booth on Perryville Karst, East Perry County Fair September 2008, Approximately 5,000+ in attendance.
- Local National Public Radio (NPR) radio station KRCU 90.9 FM conducted a radio interview in Tom Moore Cave that focused on the Perryville Karst and cave fauna, August 2009.

- Informational Booth on Perryville Karst and Water Quality Issues, East Perry County Fair, September 2009, Approximately 5,000+ in attendance.
- Presentation on Global Information System (GIS) information and water quality issues to the Southeast Regional Planning Commission in Perryville, October 2009.
- Presentation on “Issues and Remedies for Our Water” was given at the Perry County Soil and Water Conservation District Annual Meeting, 23rd March 2010, approximately 230+ in attendance.
- Informational Booth on Perryville Karst, Water Quality Issues, and The Relationship of Sinkhole Buffer Strips to Crop Profitability and Water Quality, East Perry County Fair, September 2010, Approximately 5,000+ in attendance.
- Cave and Karst Workshop for teachers. Three day class presented on Perryville Karst studies and issues with field inspections of karst habitats. Twelve teachers in attendance. Presented by MDC in June 2013 at the Perryville Higher Education Center. An additional workshop was held in June 2014.
- Landowner Workshop. Presentations from UMExt, PCSWCD, NRCS, MDC on cost-share programs and Best Management Practices opportunities currently available to improve water quality and reduce excess erosion. There were 72 participants in attendance. It was held at the Perryville Higher Education Center in March 2015.

In September 2012, the USFWS held a public meeting at the Perryville Higher Education Center to discuss the potential listing of Grotto Sculpin as endangered with the caveat of designating critical habitat. Approximately 120 individuals from the area attended. Presentations were given about the listing, current management actions, and other listings within Missouri by state and federal agency staff.

It was discussed during this meeting that either the USFWS or community could develop a plan for implementing future management and protection of the watershed thus protecting Grotto Sculpin populations. If a plan was done by the community and found to be pertinent in the protection of the watershed and Grotto Sculpin then designating critical habitat could be avoided. The community quickly developed a working group and produced a plan as described earlier.

In October 2013, the USFWS designated Grotto Sculpin as endangered without the designation of critical habitat. Continued meetings and discussions have been completed with local, state and federal agencies to meet the USFWS criteria in regards to the community plan as well as the PCK Watershed Plan.

Section 2. PARTNERS AND COLLABORATORS

2.1 Watershed Partnership Committee

Due to the proposed listing of Grotto Sculpin, (*Cottus specus*), as endangered by the USFWS, the PCCEEC was formed to assess past, current, and future water quality improvement efforts in their community. This partnership includes the Perry County Farm Bureau (PCFB), PCHD, Perry County Commission, Regional Planning, City of Perryville, Perry County Economic Development Authority, Perryville Development Corporation, PCSWCD, the NRCS, MDC, USFWS, and MoDNR.

2.2 Volunteer Stream Teams and Grotto Clubs

Volunteers from the local streams teams and Grotto Clubs in the area and in the southeast region have been and will continue to be utilized to collect pertinent water quality monitoring to be used by MoDNR, aid in cleaning out tires from sinkholes as well as aid in vegetative buffer plantings and maintenance. It is planned to use these volunteers on numerous activities for improving PCK water quality. These groups will also be a vital component in outreach and education events and activities. Additional cave organizations can include but are not limited to the Missouri Speleological Survey, Cave Research Foundation (MSS/CRF), and Missouri Caves and Karst Conservancy (MCKC) and can aid in the collection of additional data and cave surveys.

2.3 Other Volunteers

Volunteers will be solicited from the community, willing partners, university clubs, and Grotto Clubs. By using a variety of volunteer groups we can further public education and community involvement.

PERRY COUNTY KARST WATERSHED

Section 3. WATERSHED DESCRIPTION

3.1 Physical and Natural Features

Groundwater flow paths do not fit with the surface topography within the PCK area. Therefore, the project area was not determined by a specific watershed but instead partially by the boundaries of the Perryville Karst Region and partially by the political boundaries of Perry County (Figure 3.1). This will be explained further below.

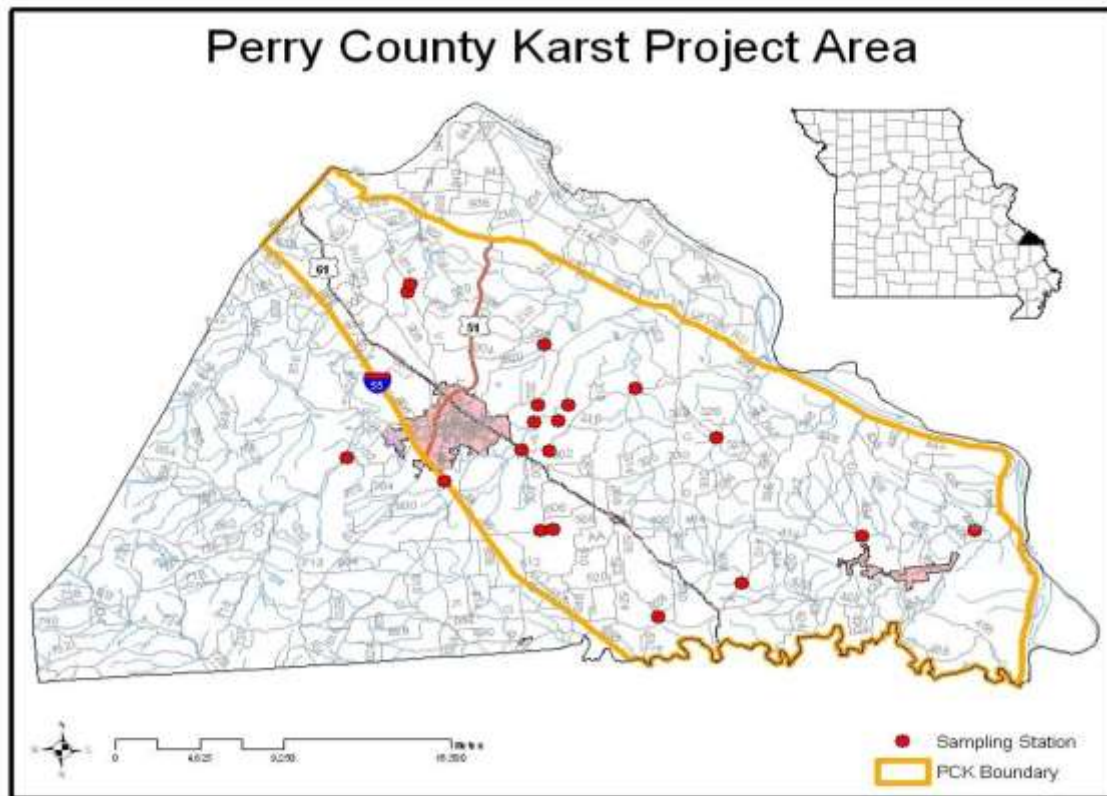


Figure 3.1. Perry County Karst project area boundaries.

3.1.1 Watershed Boundaries

There are two sets of watershed boundaries for Perry County. The first is comprised of surface watersheds as found in Figure 3.2 and Table 3.1 (CARES 2003).

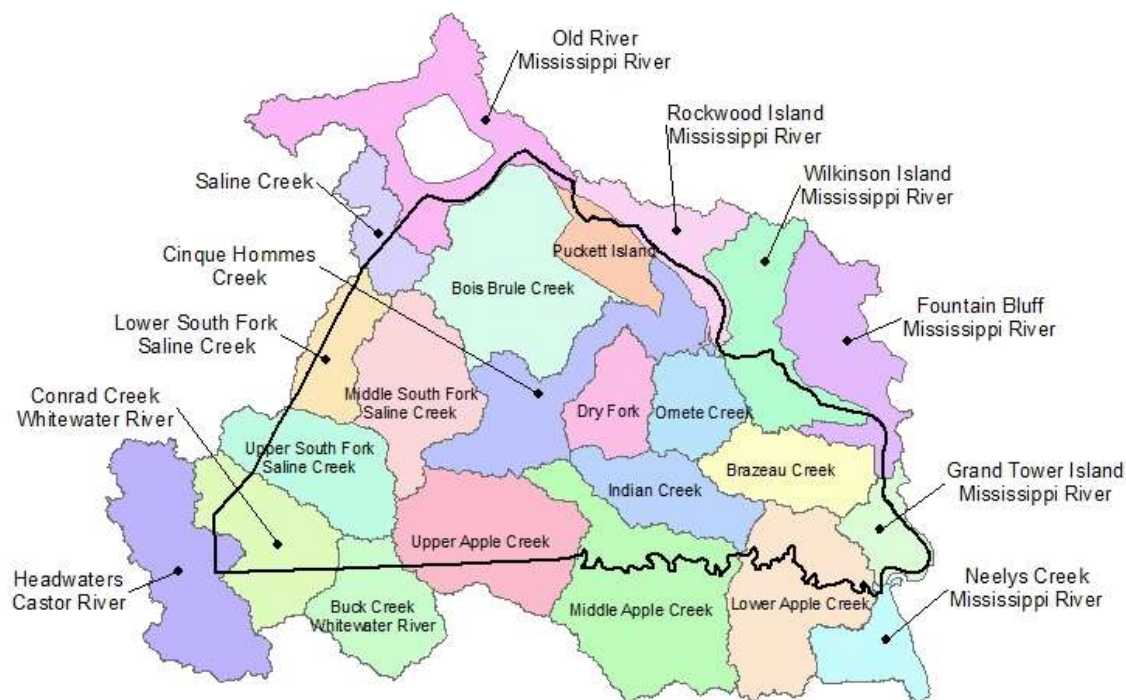


Figure 3.2. Sub-watersheds in Perry County, Missouri (12-digit HUC).

Table 3.1. Sub-watersheds in Perry County, Missouri (12-digit HUC).

12-Digit HUC	Subwatershed Name
071401050114	Old River – Mississippi River
071401050306	Rockwood Island – Mississippi River
071401050307	Wilkinson Island – Mississippi River
071401050309	Fountain Bluff – Mississippi River
071401050310	Grand Tower Island – Mississippi River
071401050405	Neelys Creek – Mississippi River
071401050108	Upper South Fork Saline Creek
071401050109	Middle South Fork Saline Creek
071401050110	Lower South Fork Saline Creek
071401050113	Saline Creek
071401050301	Bois Brule Creek
071401050302	Dry Fork
071401050303	Puckett Island
071401050304	Omete Creek
071401050305	Cinque Hommes Creek
071401050308	Brazeau Creek
071401050401	Upper Apple Creek
071401050403	Middle Apple Creek
071401050404	Lower Apple Creek
071401050402	Indian Creek
071401070201	Headwaters Castor River
071401070501	Conrad Creek – Whitewater River
071401070502	Buck Creek – Whitewater River

The second is comprised of the subsurface watersheds (recharge areas) that were determined during this project for the major cave systems within the project area (see 3.1.5 Groundwater Resources for recharge area delineations). The area exhibits the typical watershed appearance in most areas however within the recharge areas surface runoff is not accumulated in defined stream channels but enters groundwater inputs (i.e., sinkholes). These areas can be seen in Figure 3.3 as lacking surface streams indicating the subsurface systems as the predominate watersheds. As an example, the area south of Perryville between Interstate 55 and Highway 61 lacks surface streams but corresponds with the recharge area of Mystery Cave, as illustrated in Figure 3.10 of Section 3.1.5 Groundwater Resources.

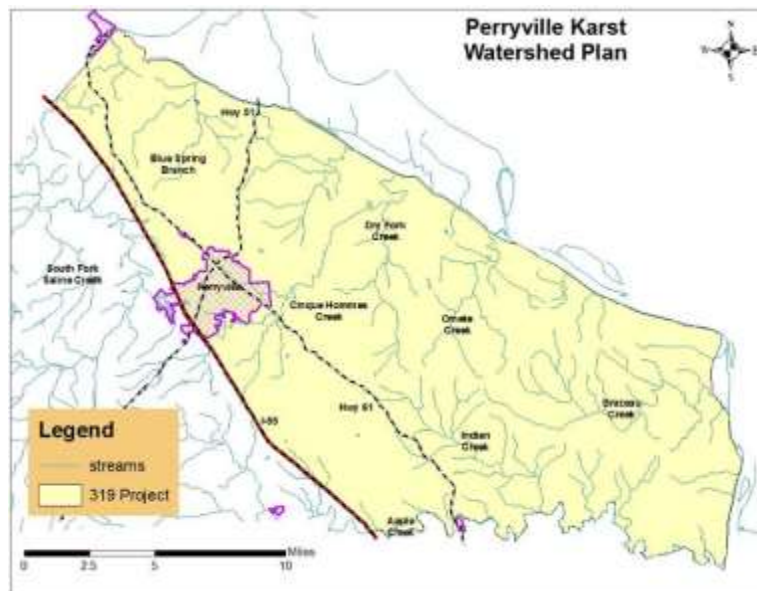


Figure 3.3. Surface stream distribution in the Perry County Karst project area.

3.1.2 Hydrology

The surface streams are classified as Ozark border streams. The upper reaches of these streams have gravel and bedrock bottoms with riffle/pool complexes. The lower reaches have sediment-based bottoms with mainly runs. The substrate and channel complexes associated with these streams can be attributed to gradient changes throughout the surface streams. The subsurface streams cannot really be categorized by the same stream classification used for surface streams. Subsurface streams in the Perryville Karst have riffles, pools, and runs. The subsurface stream bottoms are commonly comprised of coarse bedrock with some boulders, gravel, and in some longer runs, fine sediments. Both surface and subsurface streams in the project area have flow regimes that are precipitation driven, Figure 3.4. Stream flow is normally at base flow until a precipitation event which results in a drastic increase and decline in flow as the stream returns to base flow.

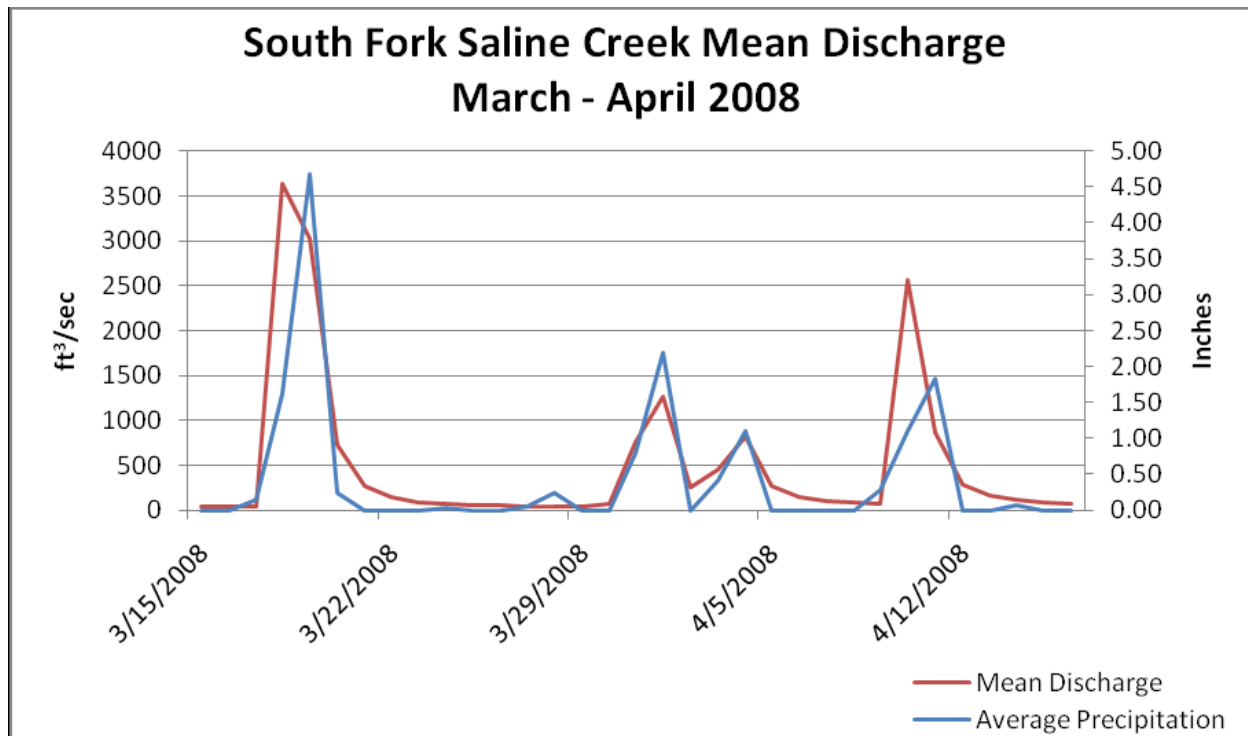


Figure 3.4. Stream discharge versus precipitation in the South Fork of Saline Creek drainage.

3.1.3 Climate/Precipitation

Southeast Missouri has a humid, temperate climate. To gain a better understanding of the variability of weather patterns impacting the project area; climate data was collected from three different sources, the Perry County Drinking Water Treatment Facility located approximately five miles northwest of Perryville, Figure 3.5, Community Collaborative Rain, Hail, and Snow (CoCoRaHS) Network with a station located at the United States Department of Agriculture (USDA) Farm Services Agency (FSA) in Perryville, Figure 3.6, and an on-site HOBO® remote sensing weather station located at the Blue Spring Branch Conservation Area (MDC lands leased from L-A-D Foundation a non-profit organization started by Leo Drey) farm, approximately 15 miles north of Perryville, where the vertical drain buffer monitoring was conducted, Figure 3.7. Vertical drains are defined by the NRCS as a well, pipe, pit, or bore in porous, underground strata into which drainage water can be discharged without contaminating groundwater resources. The purpose of these structures is to provide drainage for water from surface to subsurface areas reducing the potential for soil erosion. This practice is commonly used in Perry County for reducing sinkhole erosion and expansion. Precipitation data was the primary focus as it has the most direct impact on the surface and groundwater systems and carrying NPS pollutants such as bacteria, sediment, nutrients, and other chemicals. While the general trend in monthly rainfall averages is apparent, the variability in the monthly averages is noticeable.

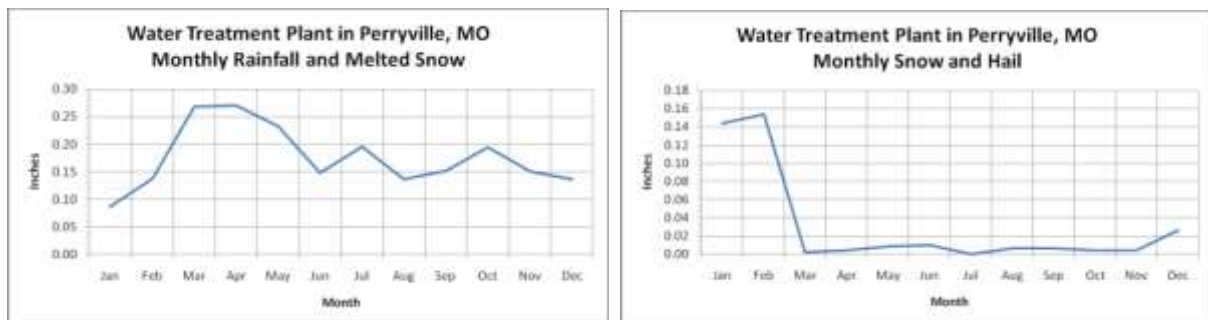
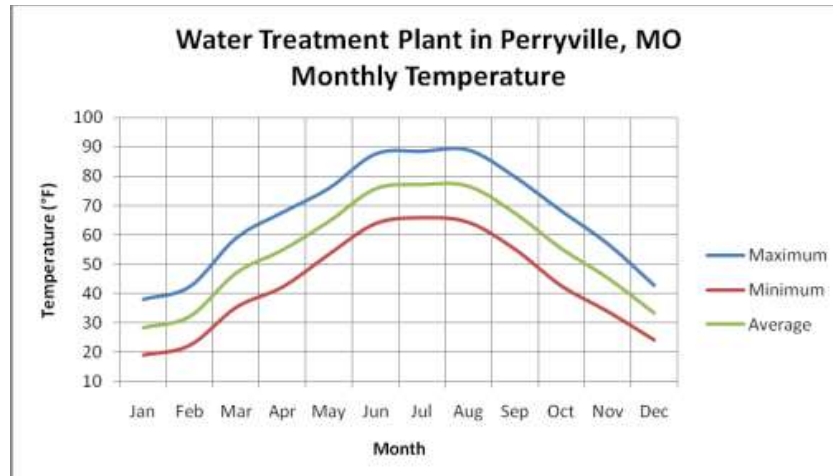


Figure 3.5. Perry County Drinking Water Treatment Facility NOAA weather station.

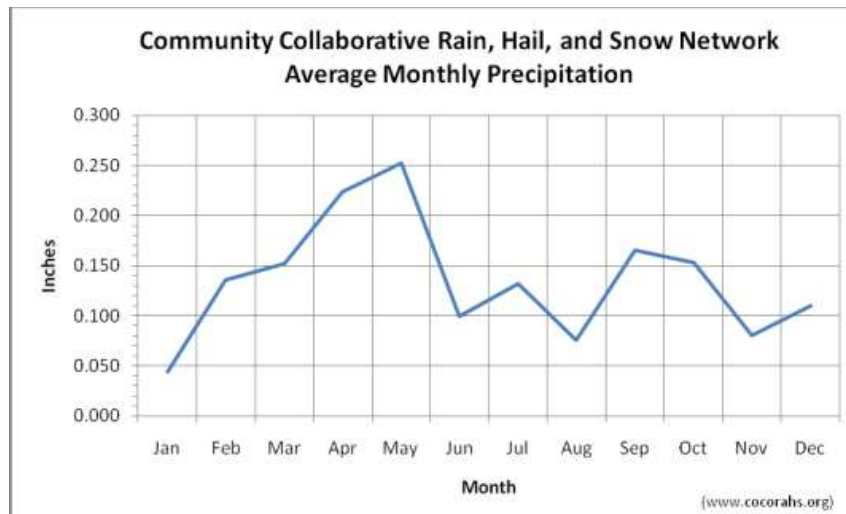


Figure 3.6. The USDA, Farm Services Agency, CoCoRaHS Network weather station.

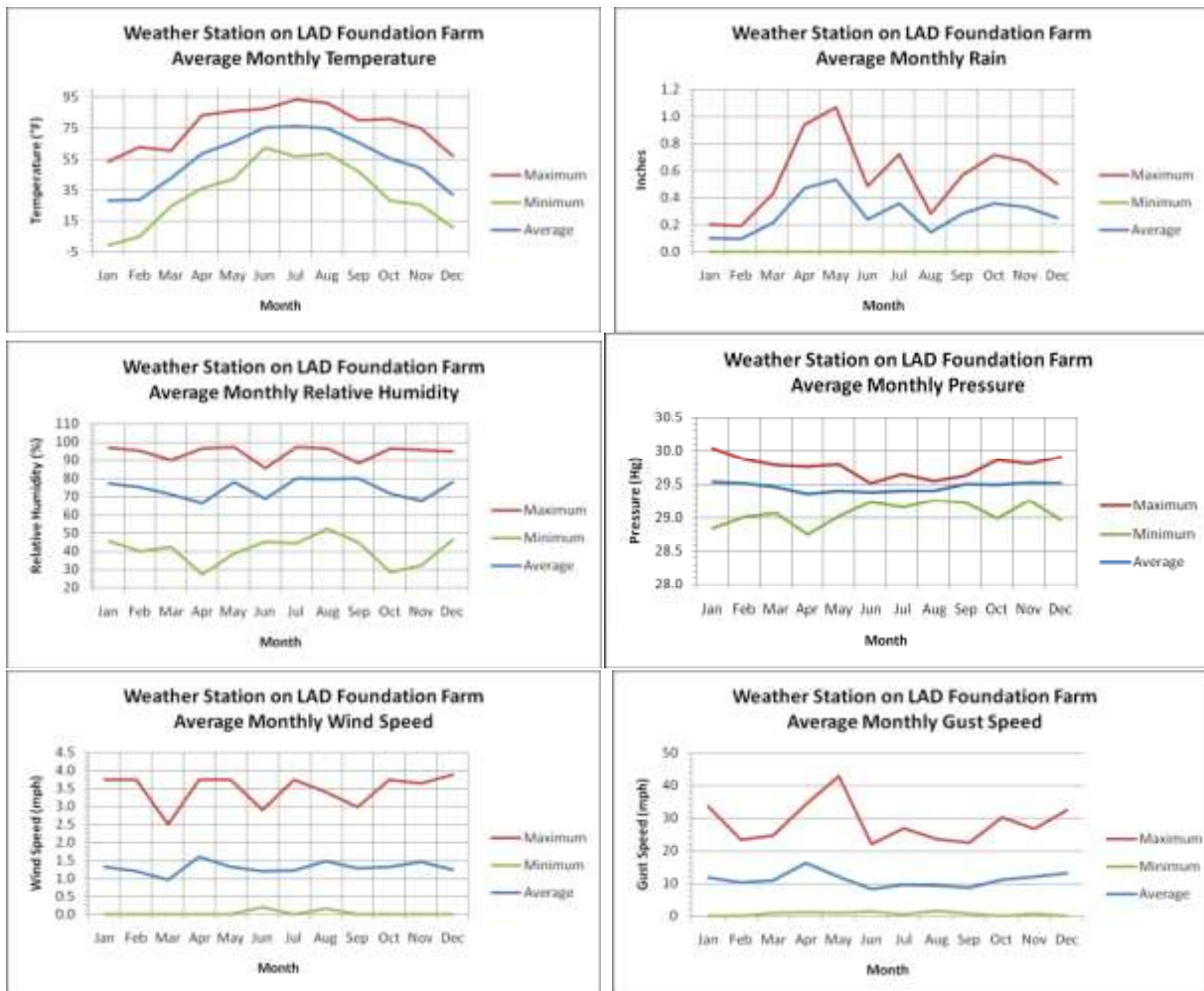


Figure 3.7. On-site HOBO® remote sensing weather station located at the Blue Spring Branch Conservation Area.

3.1.4 Surface Water Resources

Surface water resources within Perry County consist of private and public lakes, streams, and springs (Figure 3.3). There are 29 lakes, totaling 92 surface acres, which are assigned designated uses in Missouri's Water Quality Standards. Approximately 627 miles of streams in Perry County are assigned designated uses. Designated uses are the uses for a water body defined in the Missouri Water Quality Standards at 10 CSR 20-7.031(1)(C) and assigned per 10 CSR 20-7.031(2) and Table H. Such uses include aquatic life protection, recreation (e.g., swimming and boating), human health protection, irrigation, livestock and wildlife protection, and in some cases drinking water supply. These uses must be maintained in accordance with the federal Clean Water Act. Water bodies that are not meeting their designated uses are identified as impaired by MoDNR and are included on Missouri's 303(d) list of impaired waters. Five streams are currently not attaining recreational designated uses and are included on Missouri's 2018 303(d) list. These streams include:

- Brazeau Creek, water body ID 1796;
- Cinque Hommes Creek, water body ID 1781;
- Dry Fork, water body ID 1792;

- McClanahan Creek, water body ID 1786; and
- Omete Creek, water body ID 1794.

The majority of streams in Perry County are 1st and 2nd order streams. Stream orders are a way to classify streams by size and function. Strahlers (1952) determined that 1st order streams are the smallest headwater channels that only carry water during precipitation events. These streams are typically found in the upland areas of watersheds. As two 1st order streams come together they form a 2nd order stream at that junction. A 3rd order stream is formed at the junction of two 2nd order streams, etc. The larger streams are 3rd order, i.e., Indian, Brazeau, Omete, Dry Fork and Cinque Hommes above Highway 61, and 4th order streams, i.e., Apple, Cinque Hommes below Highway 61 and South Fork Saline. The City of Perryville and surrounding area utilize water from South Fork Saline Creek as a drinking water source. Other portions of the county utilize public rural water wells. Approximately 1/3 of the county has private wells as a drinking water source (Figure 4.4).

There are 46 documented springs (Figure 3.8), however, there are a considerable number of springs that are undocumented (CARES 2016). The majority of the ponds are one acre and less with a small percentage larger than one acre (PCSWCD 2012).

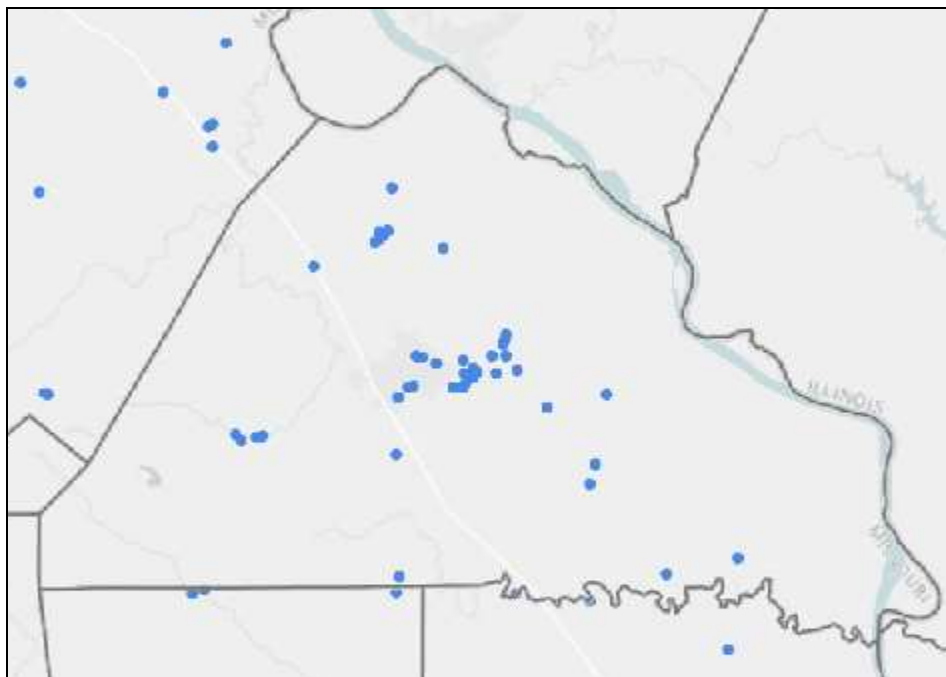


Figure 3.8. Documented springs located in Perry County, Missouri.

3.1.5 Groundwater Resources

Perry County lies within the Ozark Plateau aquifer system and has portions of the Ozark aquifer and the Major River Valleys groundwater region (Figure 3.9; Mesko and Berkas 1986).

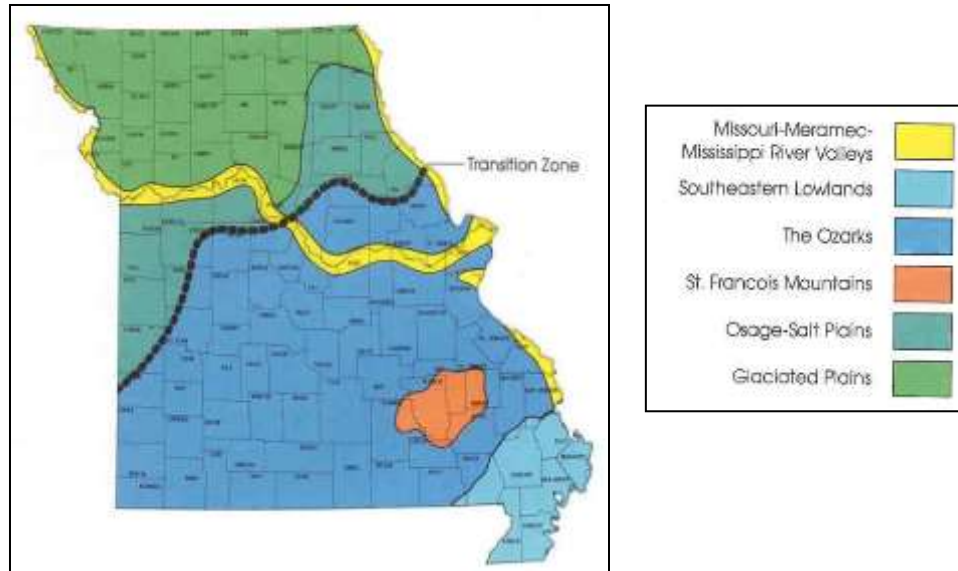


Figure 3.9. Aquifers of the Ozark Plateau aquifer system.

The NPS-WMP will focus on impacts to the Ozark aquifer. Water movement within the aquifer tends to be northeastward in the northern portion of the county and southeastward in the southern portion of the county (Figure 3.10; Miller and Appel 1997).

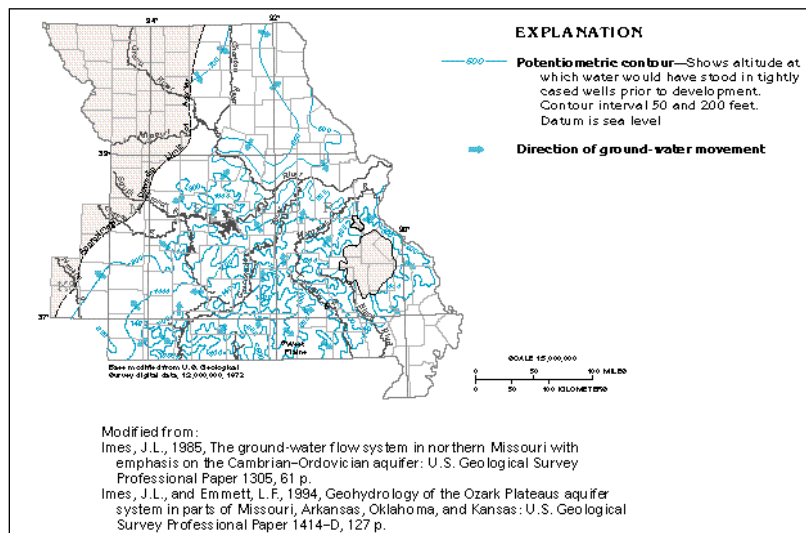


Figure 3.10. Groundwater movement in the Missouri portion of the Ozark aquifer.

Since the Perryville Karst is situated above the Ozark aquifer, a shallower groundwater system is present in the management area. This karst area is considered a perched open system and would be more appropriately termed a conduit aquifer (White 1988). The perched karst system lies within the vadose zone close to the surface which is underlain by relatively impervious rock units separating it from the phreatic zone (Palmer 2007). In the vadose zone, water movement is dominated by gravity and the perched streams within these caves flow downward towards the surface streams with a direct connection via multiple conduits and resurgences (Figure 3.11). This system is also characterized by numerous sinkhole inputs and heavy sediment loads which is commonly documented in perched open

karst systems. Dye tracing studies and cave maps are the best way to gain an understanding of the connectivity, movement, and recharge areas of the shallower groundwater system.

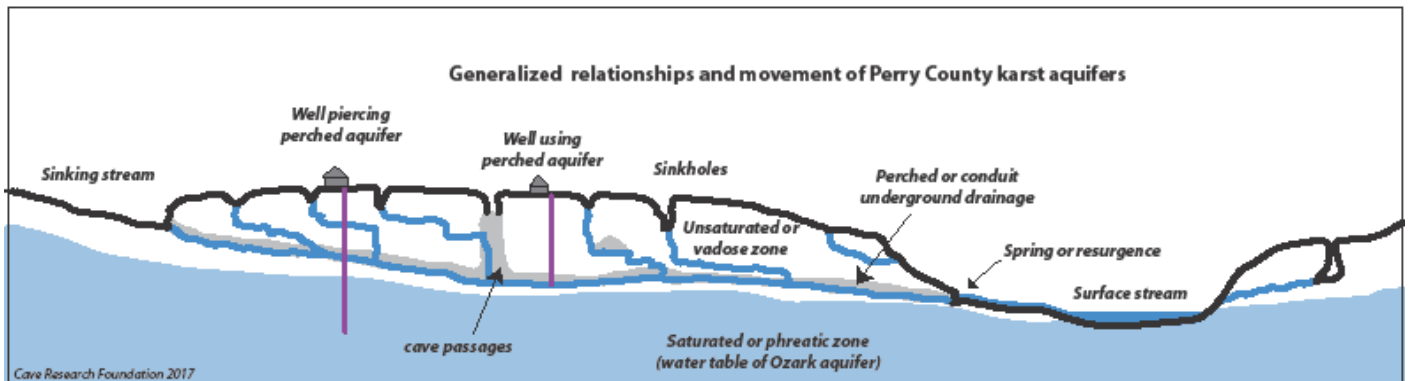


Figure 3.11. Diagram of shallow groundwater system present in the Perry County Karst watershed.

Over the past years, there has been five karst dye tracing studies, Vandike (1985), Schooler (1996), Crawford (2006), Sides (personnel communication 2007), and Aley and Moss (2007). These earlier studies were conducted to determine the recharge areas for the major cave systems in the Perryville Karst and to look at stormwater runoff issues in the City of Perryville. These studies were funded through a 319 grant administered by MDNR. The latest dye tracing efforts (Moss and Pobst 2010) picked up where earlier studies left off, repeated inconclusive traces, and summarized the data of earlier and current traces in order to determine the most complete picture of the recharge areas.

During the most recent study, there were 87 dye introductions conducted in the Perryville Karst (Figure 3.12). These introductions were used to delineate recharge areas for eight major cave systems in the Perryville Karst and include a total of approximately 94.0 square km (36.3 square miles; Figure 3.12). Some of the introductions went to other springs that need additional tracing to delineate their recharge areas.

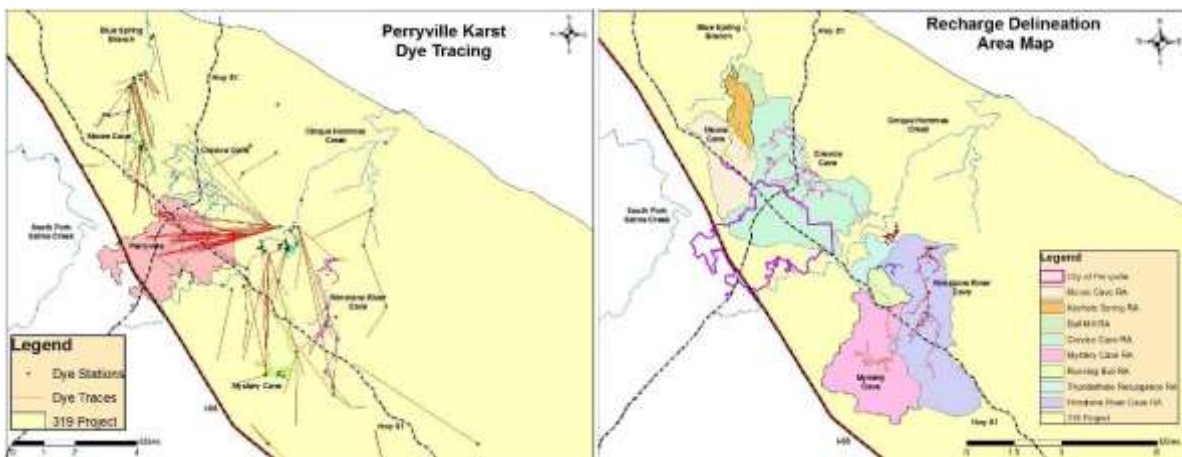


Figure 3.12. Dye traces in the Perryville Karst and Recharge Areas of the major cave systems in Perry County, Missouri.

Moore Cave System Recharge Area

The recharge area of the Moore Cave System is approximately 3.95 square miles (2,528 acres) (Figure 3.13). The cave is currently ranked as the third longest known cave system in Missouri with 18.0 miles of mapped passage (Hauck, 1980). The system drains north from the edge of Perryville and discharges at Blue Spring on Blue Spring Branch and can overflow from a nearby spring called Blue Spring Overflow or Blue Spring Resurgence (Moss and Pobst 2010). Most of the cave lies underneath the Keyhole Recharge Area. During heavy rain events some of the runoff in southeast portion of the recharge area will discharge into Crevice Cave. A portion of the Perryville City limits is in this recharge area and it is expected that the city will expand in this direction. It is recommended that additional dye tracing be conducted to determine recharge areas for smaller watersheds that drain into tributaries within the Moore Cave System.

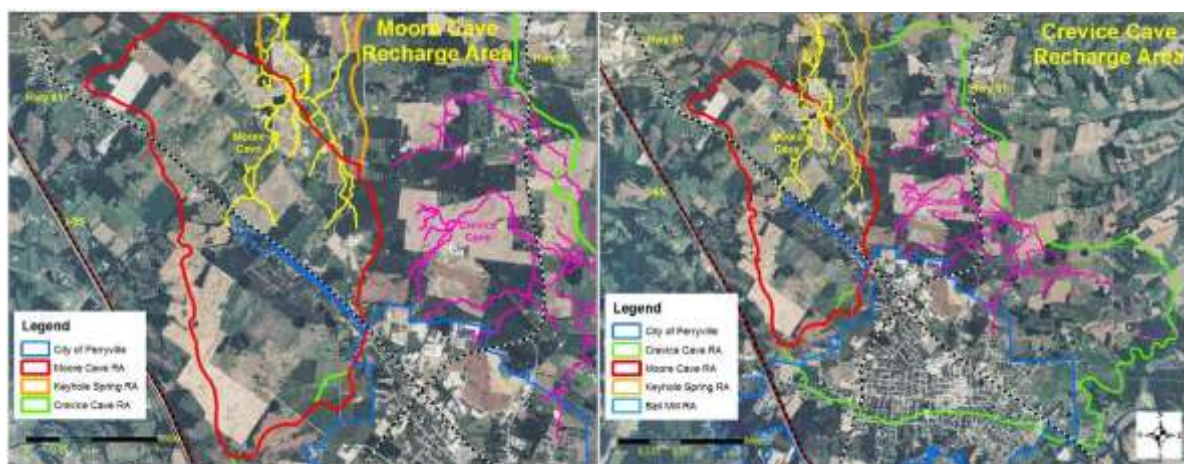


Figure 3.13. Moore Cave Recharge Area and Crevice Cave Recharge Area.

Crevice Cave System Recharge Area

The recharge area of the Crevice Cave System is approximately 11.71 square miles (7,494.4 acres) and is the largest recharge area of the caves investigated in Perry County (Figure 3.12; Moss and Pobst 2010). The cave is currently the longest cave known in Missouri with approximately 30 miles of mapped passage (Gulden 2010) and has a relatively short sump separating it from Mertz Cave, which has 2.05 miles of mapped passage (Coons 1974). Together, the system has approximately 32 miles of mapped passage. The system drains south from Perryville and Perryville Industrial Park, which includes TG Missouri, Gilster-Mary Lee Corporation, TNT Plastics, Inc., and discharges at Mertz Resurgence on Cinque Hommes Creek. Most of the City of Perryville will drain into the Crevice Cave System (Figure 3.13). The Crevice Cave groundwater system is very unusual in that much of the western part does not stay underground. Water can be discharged from Circle Drive Resurgence, Heberlie Resurgence, and Doc White Spring and then sink back into the Crevice Cave groundwater system to be discharged from Mertz Resurgence. At higher flows, some of the water discharged to the surface will stay on the surface (Moss and Pobst 2010). It is recommended that additional dye tracing be conducted to determine recharge areas for smaller watersheds that drain into tributaries within the Crevice Cave System.

Mystery Cave System Recharge Area

The recharge area of the Mystery Cave System is approximately 7.05 square miles (4,512 acres) (Figure 3.14). The cave has at least 15.8 miles of mapped passage (Gulden 2010) and more than 1.5 miles of passage mapped in peripheral caves for a system length of at least 17.3 miles. The system drains north and discharges at Mystery Resurgence on Cinque Hommes Creek. During very high flow events it can over flow to Mystery Overflow Spring, Miller Spring, and discharge from the mouth of Maple Leaf Cave, Thunderhole Resurgence, and Blue Spring (a separate spring from Blue Spring associated with Moore Cave System Resurgence) farther downstream on Cinque Hommes Creek (Moss and Pobst 2010).

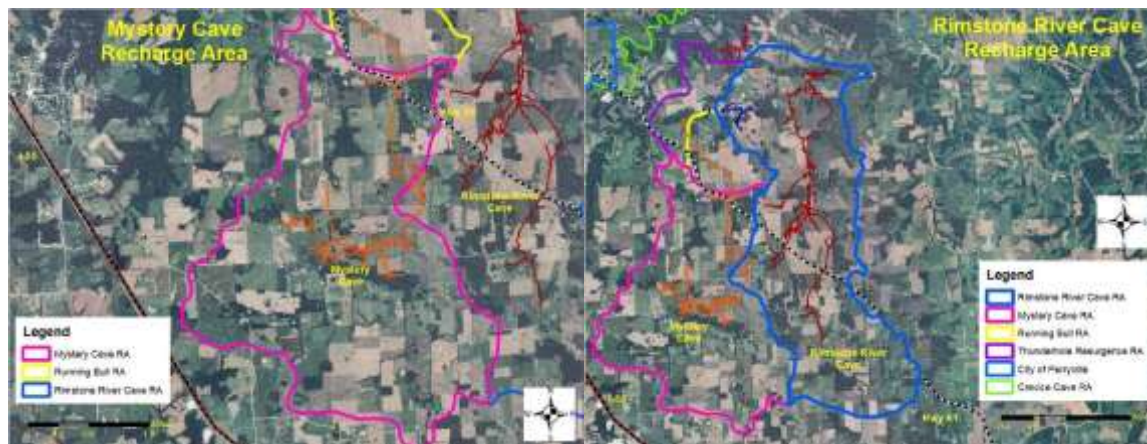


Figure 3.14. Mystery Cave Recharge Area and Rimstone River Cave Recharge Area.

Rimstone River Cave Recharge Area

The recharge area of the Rimstone River Cave System is approximately 9.47 square miles (6,060.8 acres; Figure 3.14). Rimstone River Cave has 14.2 miles of mapped passage (Gulden 2010) and the downstream Hot Caverns has 3.1 miles (Moss 1987) and there are other associated caves in the system with at least another 0.7 miles of mapped passage in peripheral caves making the cave system 18.0 miles long. The system drains to the north and discharges solely from Cedar Spring on Cinque Hommes Creek (Moss and Pobst 2010).

Running Bull Cave Recharge Area

The recharge area of the Running Bull Cave System is approximately 1.06 square miles (678.4 acres; Figure 3.15). The cave only has 1,345 feet of mapped passage (Moss, personal communication 2008). The system drains to the north through Maple Leaf Cave and discharges from Miller Spring when it is flowing, from the mouth of Maple Leaf Cave and Blue Spring at high flows, at Thunderhole Resurgence on Cinque Hommes Creek (Moss and Pobst 2010).

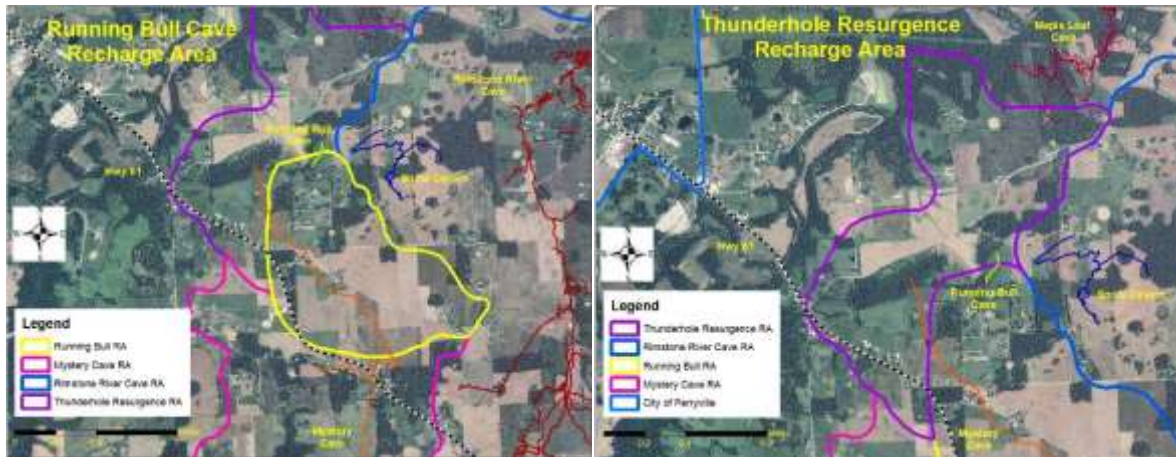


Figure 3.15. Running Bull Cave Recharge Area and Thunderhole Resurgence Recharge Area.

Thunderhole Resurgence Recharge Area

The recharge area of the Thunderhole Resurgence System is approximately 2.15 square miles (1,376 acres) at base flow, which includes the Running Bull Cave recharge area (Figure 3.15). However, since the Mystery Cave groundwater system can overflow to it, at high flows the Thunderhole Resurgence recharge area is approximately 9.20 square miles (Moss and Pobst 2010).

Keyhole Spring Recharge Area

The recharge area of the Keyhole Spring System is approximately 1.29 square miles (825.6 acres; Figure 3.16). The groundwater to this spring flows north and is located on the south side of Blue Spring Branch and downstream from Blue Spring (Moore Cave System; Moss and Pobst 2010). It is recommended that additional dye tracing be conducted for more accurate recharge area delineation.



Figure 3.16. Keyhole Spring and Ball Mill Recharge Areas.

Ball Mill Spring Recharge Area

The recharge area of the Ball Mill Spring System is approximately 0.66 square miles (422.4 acres; Figure 3.16). The groundwater to this spring flows north and is located on the south side of Blue Spring Branch and is further east and downstream than is Keyhole Spring (Moss and Pobst 2010). Additional dye traces are needed for this recharge area and to determine if outflow during high flow events occurs at Ball Mill Resurgence.

3.1.6 Topography/Elevation

The central portion of Perry County has a rolling topography with elevations of 520 feet to 660 feet above sea level. This area has the underlying Perryville Karst, which exhibits the typical karst plain appearance of being thoroughly marked by sinkholes (Figure 3.17). Steeper, dissected hills are found in the eastern part of the county along the Mississippi River floodplain and in the western part of the county west of Interstate 55. These areas lack the underlying karst geology found predominately in the central portion of Perry County.



Figure 3.17. Surface features of the Perryville Karst in Perry County, Missouri.

3.1.7 Geology and Soils

Within the Ozark Plateau, Perry County is on the northeastern edge of the Salem Plateau (Figure 3.18; Dom and Wicks 2003). The rocks in Perry County are primarily Ordovician (Figure 3.19; Unklesbay and Vineyard 1992) with lower Ordovician sedimentary rocks located west of Interstate 55 and Middle Ordovician and younger rocks located east of Interstate 55.



Figure 3.18. The sub-divisions of the Ozark Plateau.



Figure 3.19. The generalized geologic map of Missouri.

Figure 3.20 illustrates the geologic order of the formations (Schooler 1996) while Figure 3.21, though cropped to only a portion of the county, illustrates how the formations are arranged in the county (Vandike 1985).

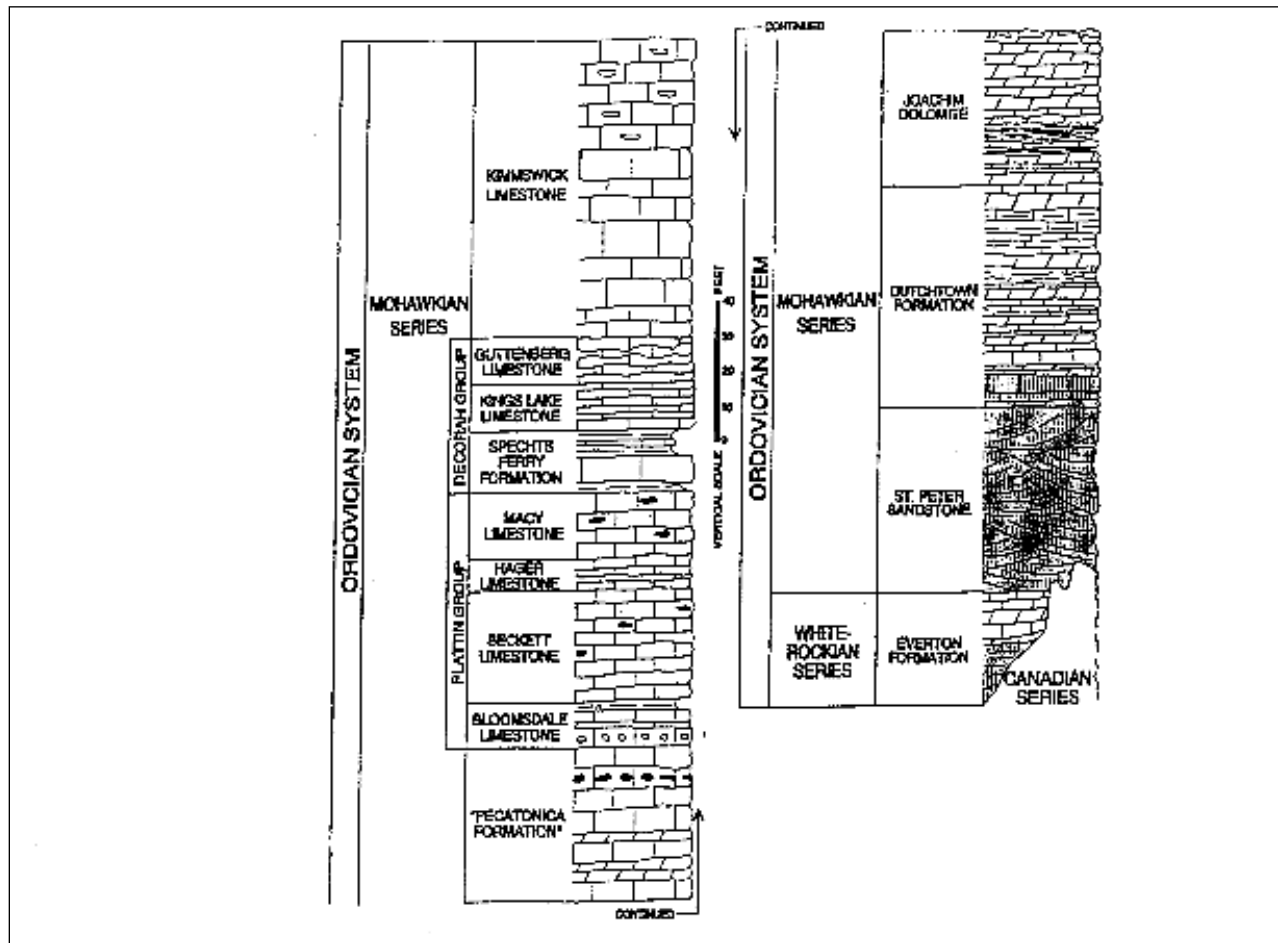


Figure 3.20. Ordovician System, White-Rockian and Mohawkian Series.

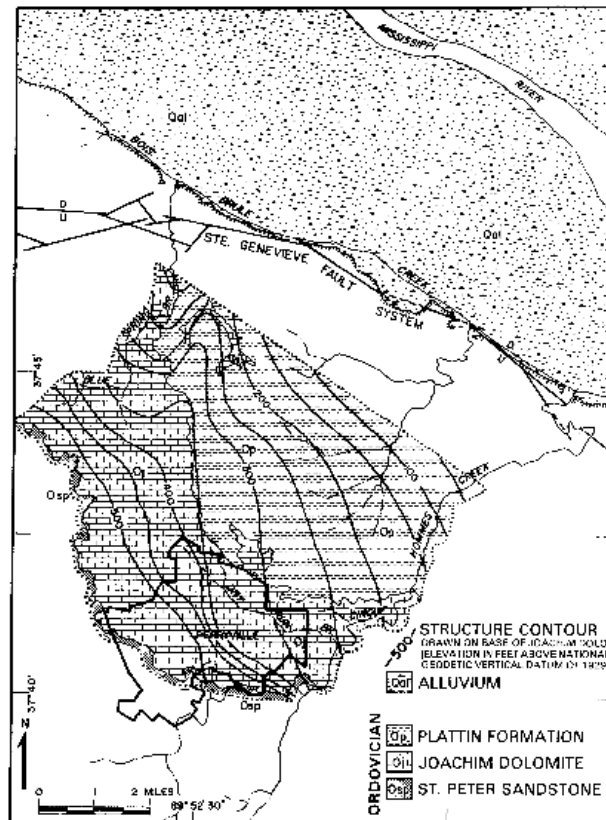


Figure 3.21. Geologic and structure contour map of Perry County, Missouri.

The Perryville Karst is found east of Interstate 55 predominately within the Joachim Dolomite and Plattin Formation and to a lesser extent in the Kimmswick formation. The area is characterized by an extensive sinkhole plain that overlies the highest density of caves in Missouri (Figure 3.22; Elliott 2007).

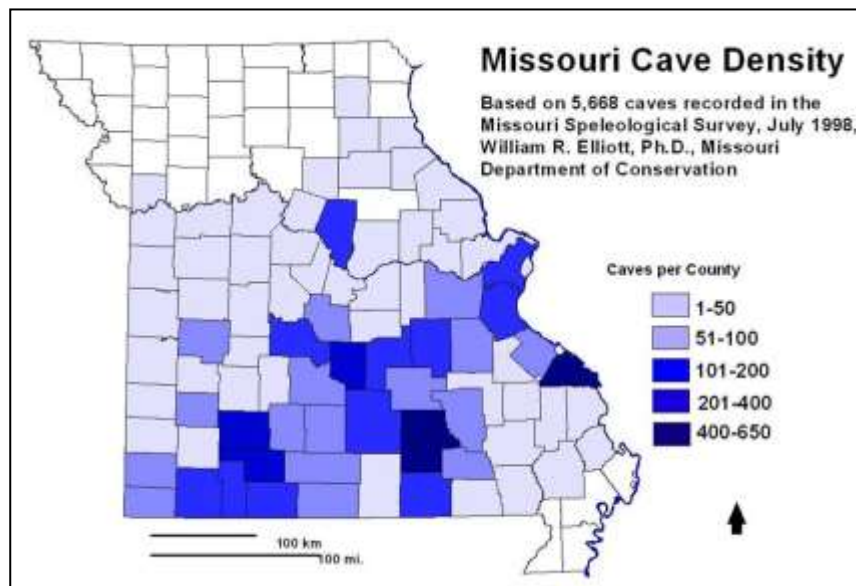


Figure 3.22. Concentrations of caves within geological formations. Missouri cave density.

The formation bordering the sinkhole plain to the west and which underlies the soluble rocks of the sinkhole plain is the St. Peter Sandstone. The Joachim Dolomite overlies the St. Peter Sandstone, which in turn is overlain by the Plattin Limestone. Some researchers split out the Pecatonica Formation between the Joachim Dolomite and Plattin Limestone, as did Dewey Amos who mapped the bedrock in the watershed (Amos; 1985a, 1985b, 1986a, 1986b, 1986c, 1987). The watershed has several feet of Quaternary loess mantling it. All of the base level cave streams appear to be in the Joachim Dolomite. Some higher-level cave passages and many cave entrances penetrate the overlying Pecatonica Formation and Plattin Limestone where it is present (Moss and Pobst 2010).

The sinkhole plain contains thousands of sinkholes with diameters ranging from a few feet to almost a mile and depths ranging from a few feet to over 100 feet (Vandike 1985). The underlying cave system has a dendritic (branch work) pattern that is indicative of high gradient, stream-based cave systems formed in the vadose (House 2009). Of the top ten longest caves in Missouri, the top four caves are found in Perry County with lengths varying from 14 to 30 miles (Unklesbay and Vineyard 1992).

Perry County soils are Quaternary loess deposits of several feet mantling residual materials (Scrivner *et al.* 1985). The A horizon ranges from 10 to 30 cm or 3.9 to 11.8 inches thick and is highly erodible and thus considered vulnerable if erosions is allowed to occur unchecked (Scrivner, Koenig, and Conkling 1985). The soil associations found in the county are mapped in Figure 3.23 with the Menfro and Haymond-Wilbur-Auxvasse Associations found in the project area (Festervand 1986).

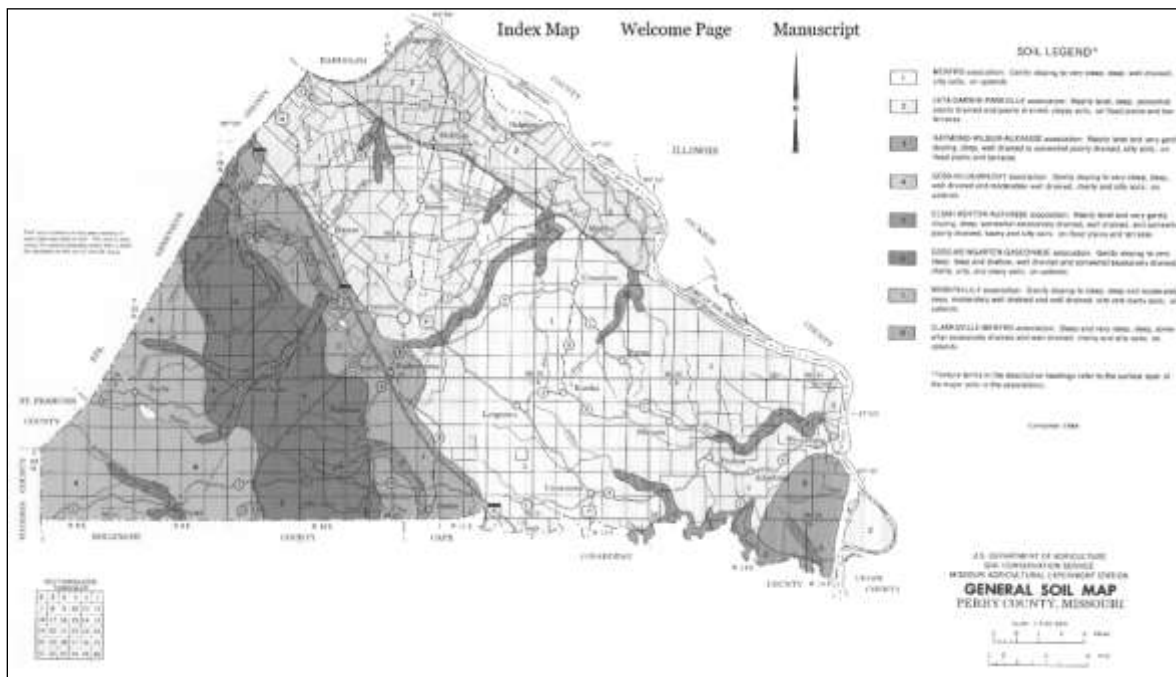


Figure 3.23. General soil map of Perry County.

The Menfro Association soils are found on the sinkhole plain, ridge tops and side slopes of long, narrow ridges that are highly dissected by narrow, V-shaped drainages. These soils have surface layers that are brown, friable silt loams and subsoil layers that are brown to dark yellowish brown, silty clay loams and silt loams. They are well drained and range from three to 50 percent slope. The

Haymond-Wilber-Auxvasse Association soils are found along the floodplains and terraces of the major surface streams. The Haymond soils have surface layers that are dark brown silt loams and subsoil layers that are dark brown and brown, mottled silt loams. They are well drained with nearly no slope. The Wilber soils have surface layers that are brown silt loams and subsoil layers that are brown to dark yellowish brown, mottled silt loams. They are moderately well drained with nearly no slope. The Auxvasse soils have surface layers that are dark grayish, brown silt loams and subsurface layers that are grayish brown to light brownish gray silt loams with subsoil layers that are brown, mottled silty clays and substratum that are grayish brown to olive gray, mottled silty clay loams. They are somewhat poorly drained with nearly no slope to very gently sloping.

3.1.8 Vegetation

Historically, the vegetation of Perry County consisted of oak savannas or “barrens” with widely scattered trees and woodland dissected plains. The barrens were tall grass prairies with trees present in some sinkholes and some scattered sinkhole ponds (Nigh and Schroeder 2002). The woodland dissected plains varied from open oak woodlands, dense well-developed forests of oak, and mixed hardwood forests in the more rugged areas. Currently, there are no remaining barrens habitat in the county, which have been replaced with fescue pastures/hay lands and agricultural crops. In 1978 the L-A-D Foundation purchased the small Ball Mill Resurgence Natural Area and then between 2007 and 2012 added adjacent and nearby lands as buffer and restoration opportunity areas. Together these lands total 279 acres and are leased to MDC to be open for the public. Under lease MDC has begun to re-establish native grass and forbs to exemplify the historical barrens habitat. These lands are indicative of the rolling Perry County karst plain, including some upland woodland areas of oak and mixed hardwoods, a small glade, and significant stretches of the more rugged Blue Spring Branch valley including bluffs, springs, and resurgences.

3.1.9 Invasive Species

The introduction of invasive species can cause extensive biodiversity loss by increasing predation and competition, causing habitat loss, genetic alterations, and possibly extinction of native species. In Missouri, there are 171 invasive species, Table 3.2 (Global Invasive Species Database; USGS-NAS; USDA Invasive and Noxious Weeds; MDA Noxious Weed Control). The number of invasive species specific to Perry County is unknown due to the lack of field surveys. However, there have been 51 species of plants documented as invasive to Perry County (EDD Maps 2013). These species are considered invasive, but are not necessarily a problem species within the county. Seven species (meadow fescue, sericea lespedeza, Japanese honeysuckle, autumn olive, multiflora rose, creeping euonymous, and Johnson grass) are considered aggressive invaders and three species (redtop, Korean lespedeza, and common lespedeza) are considered weak to moderate competitors to native plants (www.mobot.org). The aggressive invasive plant species can invade a variety of habitats including prairies, degraded meadows, woodland borders, pastures, lawns, cropland, borders of streams and ponds, and disturbed sites such as along roadsides and railroads.

Table 3.2. Invasive species found within Missouri.

Invasive species categories	Number of species
Micro-organism	3
Fungus	2
Insect	7
Mollusk	2
Crustacean	3
Fish	13
Amphibian	2
Bird	6
Mammal	3
Aquatic plant	13
Tree	14
Shrub	14
Grass	20
Herbaceous plant	59
Vine, climber	10

3.1.10 Wildlife

The wildlife within Perry County consists of aquatic, terrestrial, and troglobitic species. There are 27 species of amphibians including 11 salamanders, one newt, one mudpuppy, one spadefoot, three toads, and 10 frog species. Of these, seven species of salamanders, five species of frogs, and two species of turtles have been documented in caves (MDC 2005, Sutton 2009, MDC 2010). The county is home to 44 species of reptiles including 12 turtle, eight lizards, and 24 snake species. The Osage copperhead and timber rattlesnake are the only two venomous snakes documented in the county (Johnson 2000).

The waters of Perry County are inhabited by approximately 105 species of fish including one lamprey, two sturgeons, one paddlefish, one gar, one bowfin, one mooneye, one freshwater eel, four herrings, 39 minnows, 12 suckers, eight bullhead catfishes, one smelt, one pirate perch, three killifishes, one livebearer, one silverside, two sculpins, two temperate basses, 12 sunfish, 10 perch, and one drum species (Pflieger 1997) of which five species of fishes have been documented in caves (MDC 2005, Sutton 2009, MDC 2010).

There are 245 species of birds found in the county of which one species of bird has been documented in cave entrances (MDC 2005, Sutton 2009, MDC 2010). The county is one of few that support breeding pairs of bald eagles.

There are 51 species of mammals found in the southeastern region of Missouri, ranging from small rodents, such as field mice, to large ungulates, like white-tailed deer (Schwartz and Schwartz 1981). The number of mammals specific to Perry County is unknown due to lack of field surveys. There are 10 species of bats in the county, with most species colonizing in caves, but also roosting in large tree hollows, under bridges, and in old buildings (Boyles *et al.* 2009). Of the mammal species in the county, two species of mammals and four species of bats have been documented in caves (MDC 2005, Sutton 2009, MDC 2010).

3.1.11 Protected Species

The Missouri Department of Conservation and the USFWS (Missouri Natural Heritage Program 2013) track species on the state and federal level that are of concern, threatened, or endangered. For Perry County, there are five species that these agencies have listed. The Gray bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*) are both listed as endangered. The Gray bat colonizes in caves during the summer and winter and the Indiana bat hibernates in caves in the winter and summers along streams and rivers. Both species have been documented near Perry County; therefore, it is presumed that the occurrence of both species within the county is probable.

The Least Tern (*Sterna antillarum*), a bird that nests on the sandbars of large rivers, may reside on some of the islands along the county border near the Mississippi River. The Pallid Sturgeon (*Scaphirhynchus albus*) is a bottom dwelling fish found in areas with strong currents and sand substrate in the Mississippi and Missouri Rivers. Likewise, the Pallid Sturgeon may reside in some of the island side chutes along the county border in the Mississippi River.

The Grotto Sculpin, endemic to five cave systems in Perry County, was listed as a federal candidate species in 2002 and assigned a priority number of two (2), indicating an imminent threat to the species existence. In 2012, the USFWS proposed to designate the species as endangered. In 2013, the USFWS made a final ruling and designated the species as endangered.

The Northern Long-Eared Bat, (*Myotis septentrionalis*) range covers much of the mid-west and eastern portions of the continental United States and into Canada. This species was listed as threatened under the Endangered Species Act on April 2, 2015 due mostly to the impacts associated with white-nose syndrome.

3.1.12 Sensitive Areas

The sensitive areas of the county include the entire Perryville Karst, Saline Creek, riparian corridors, areas with trees, edge of field areas, and sinkholes. The Perryville Karst is sensitive to a wide range of disturbances such as point and nonpoint source pollutions, human activity, and loss of cave entrances. Caves are utilized by gray bats year round to raise their young and for hibernation. Indiana bats utilize caves for winter hibernation but depend upon treed areas to find hollow trees and trees with loose bark, such as shagbark hickory, to raise their young. The Grotto Sculpin currently has only been

documented in five cave systems within the county. Likewise, a recently documented troglobitic form of the digger crayfish currently is only known to utilize cave streams of two caves. Saline Creek is considered a sensitive area as it is a public water source and would be vulnerable to point and nonpoint source pollution and in-stream gravel mining. Riparian corridors, edge of field areas and sinkholes are areas that need adequate widths of permanent vegetative cover. The permanent vegetation is critical to preventing point and nonpoint source pollution from entering surface waters and groundwater.

3.2 Land Use and Land Cover

3.2.1 Open Space

3.2.2 Wetlands

3.2.3 Forested Areas

3.2.4 Agricultural Lands

3.2.5 Developed Areas

Perry County is a mixture of urban areas, forests, grasslands, and row crops. The urban areas are predominately residential with the exception of Perryville, which does have three significant manufacturing facilities. The remaining area of the county is rural. About 70% of the acres found in the sinkhole plain, along the ridge tops, and smooth-surfaces with gentle to steep side slopes, are Menfro Association soils, that have been cleared for agricultural production, pasture, and hay land. For moderately steep to very steep slopes, the Menfro Association soils have remained timbered. About 90% of the acres found along the floodplains and terraces of the major surface streams are, Haymond-Wilber-Auxvasse Association soils that have been cleared for agricultural production with only a small percentage of acres in pasture and hay land.

Figure 3.24 illustrates the present land cover of Perry County within the project area. The project area is predominately rural with only 3% categorized as urban or impervious. The project area is almost equally divided between agriculture and silviculture, 47% and 45% of the project area respectfully. The agricultural land cover is a mixture of row crops and forages/grasslands.

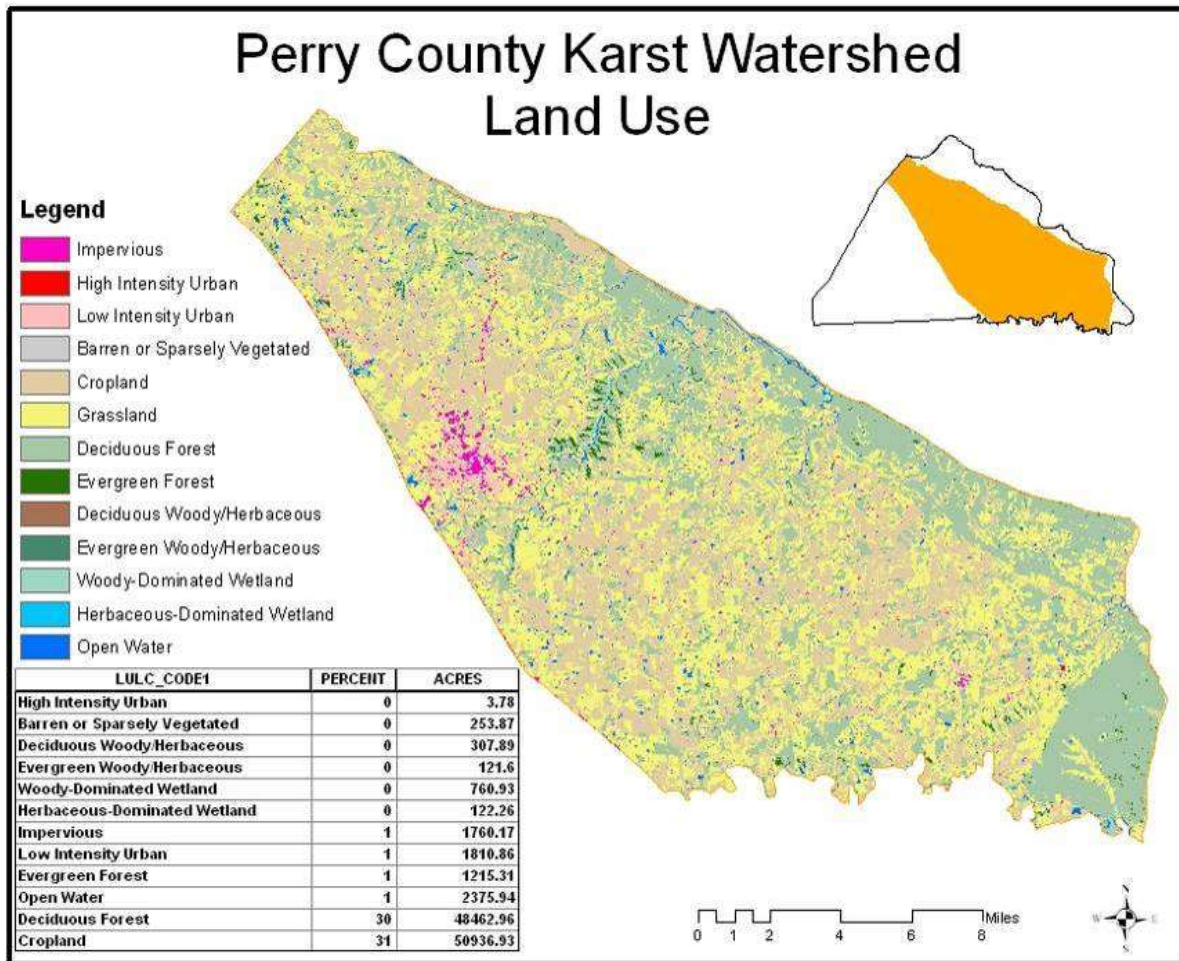


Figure 3.24. Land cover/land use of the Perry County Karst project area.

In section 3.1.5 Groundwater Resources, the delineations of the recharge areas for the major caves systems were discussed and mapped. The land cover for each recharge area is illustrated in Figures 3.25 through 3.31.

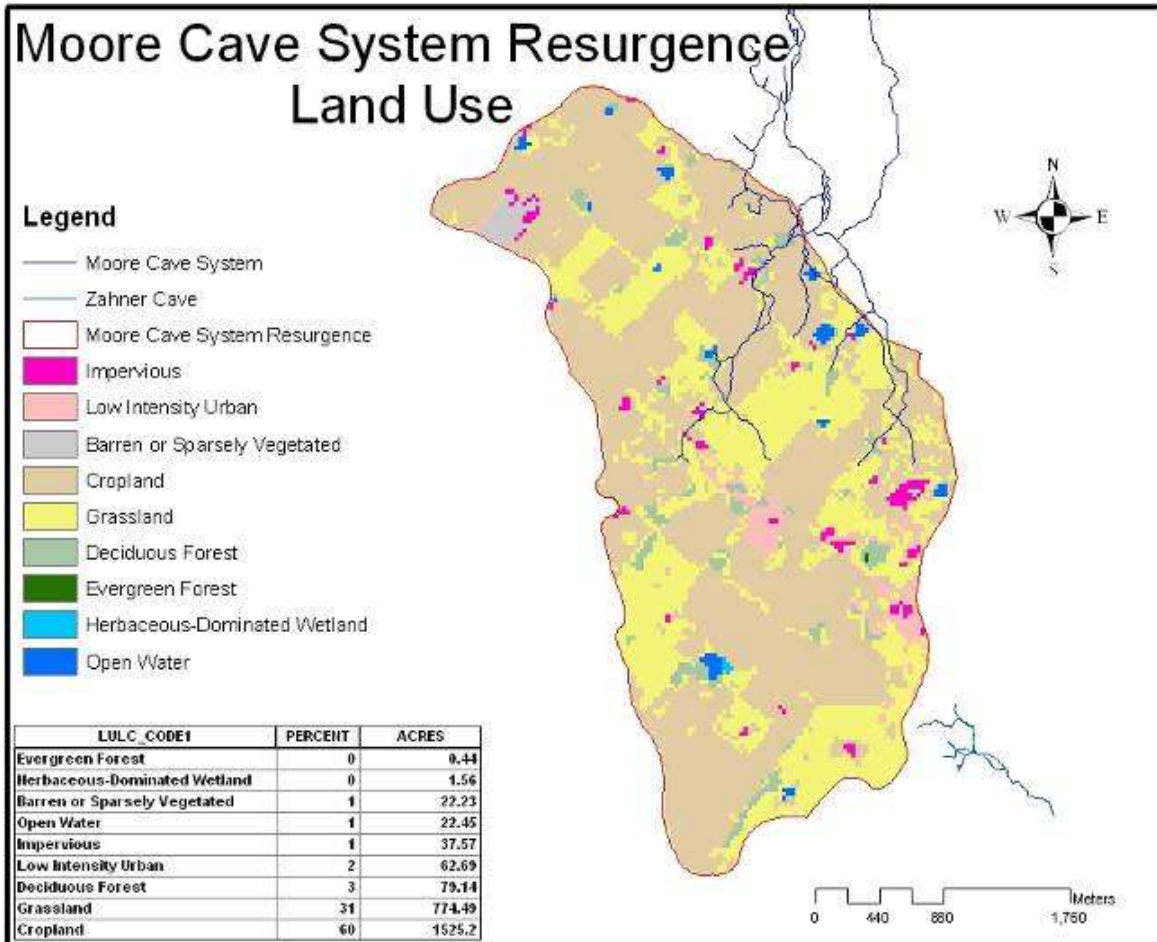


Figure 3.25. Land cover/land use of Moore Cave System Recharge Area.

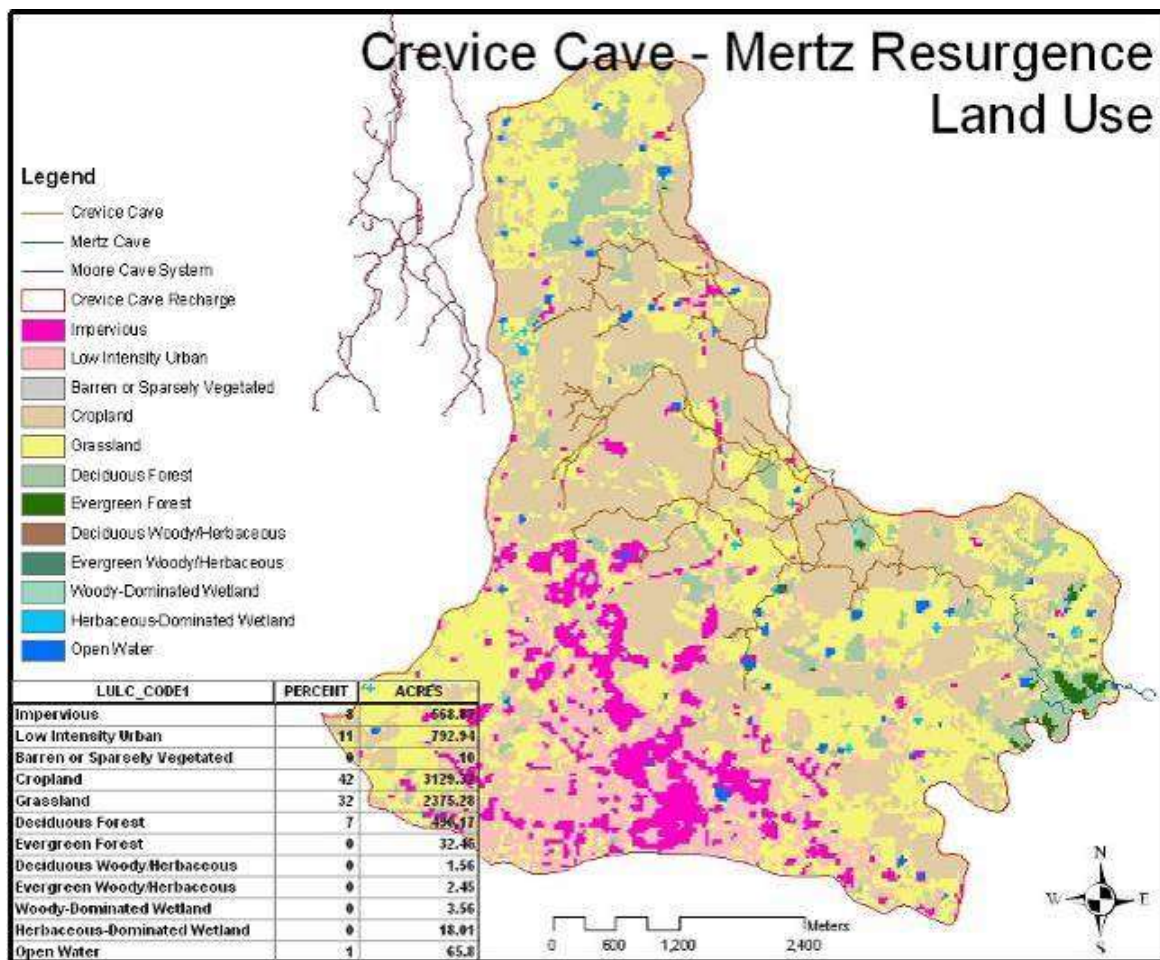


Figure 3.26. Land cover/land use of Crevice Cave System Recharge Area.

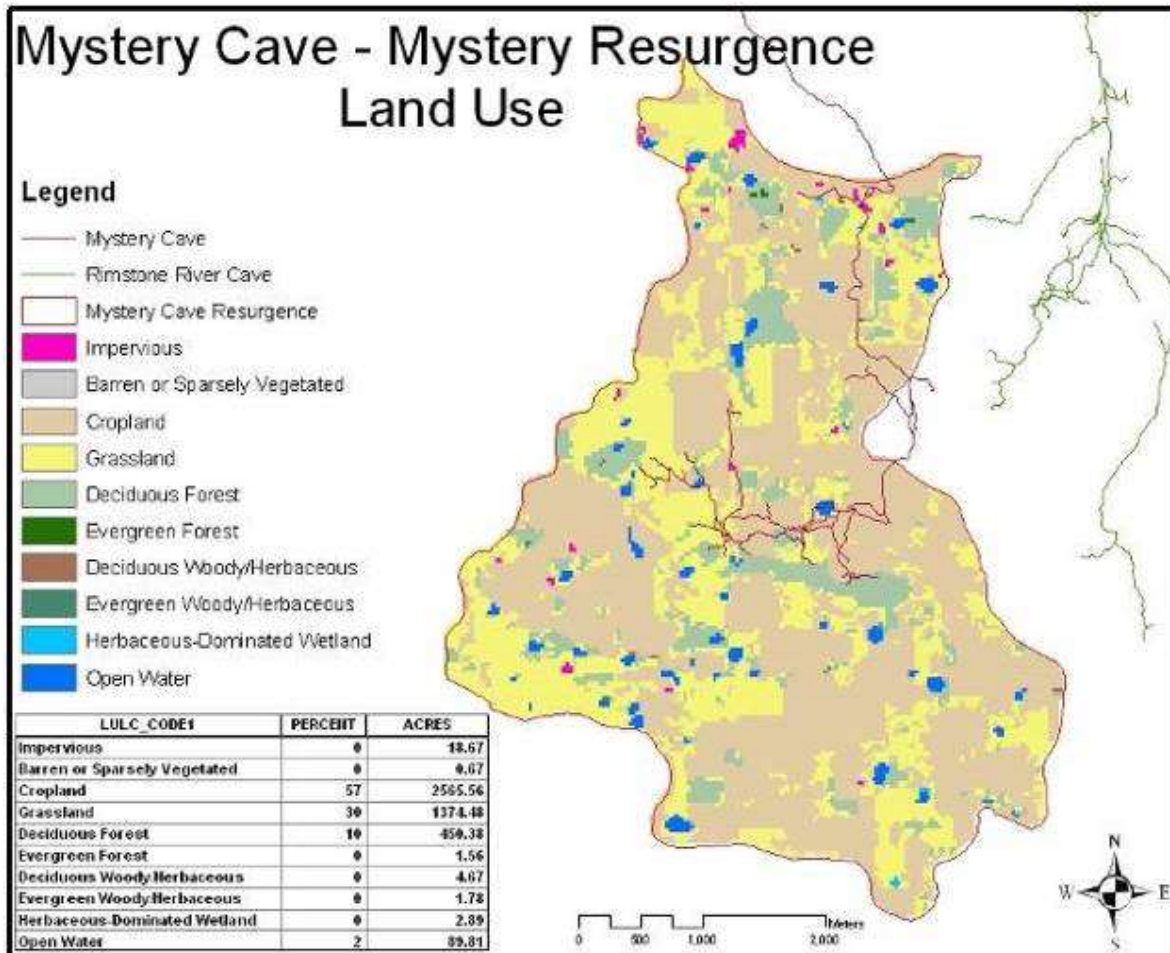


Figure 3.27. Land cover/land use of Mystery Cave System Recharge Area.

Rimstone River Cave - Cedar Spring Land Use

Legend

- Hot Caverns Elaborate
- Rimstone River Cave
- Mystery Cave
- Rimstone River Land Use
- Impervious
- Low Intensity Urban
- Barren or Sparingly Vegetated
- Cropland
- Grassland
- Deciduous Forest
- Evergreen Forest
- Deciduous Woody/Herbaceous
- Evergreen Woody/Herbaceous
- Herbaceous-Dominated Wetland
- Open Water

LULC_CODE#	PERCENT	ACRES
Impervious	0	24.68
Low Intensity Urban	0	13.12
Barren or Sparingly Vegetated	0	2
Cropland	50	3013.28
Grassland	24	2082.06
Deciduous Forest	14	834.97
Evergreen Forest	0	5.56
Deciduous Woody/Herbaceous	0	2.45
Evergreen Woody/Herbaceous	0	1.11
Herbaceous-Dominated Wetland	0	4.67
Open Water	1	75.8

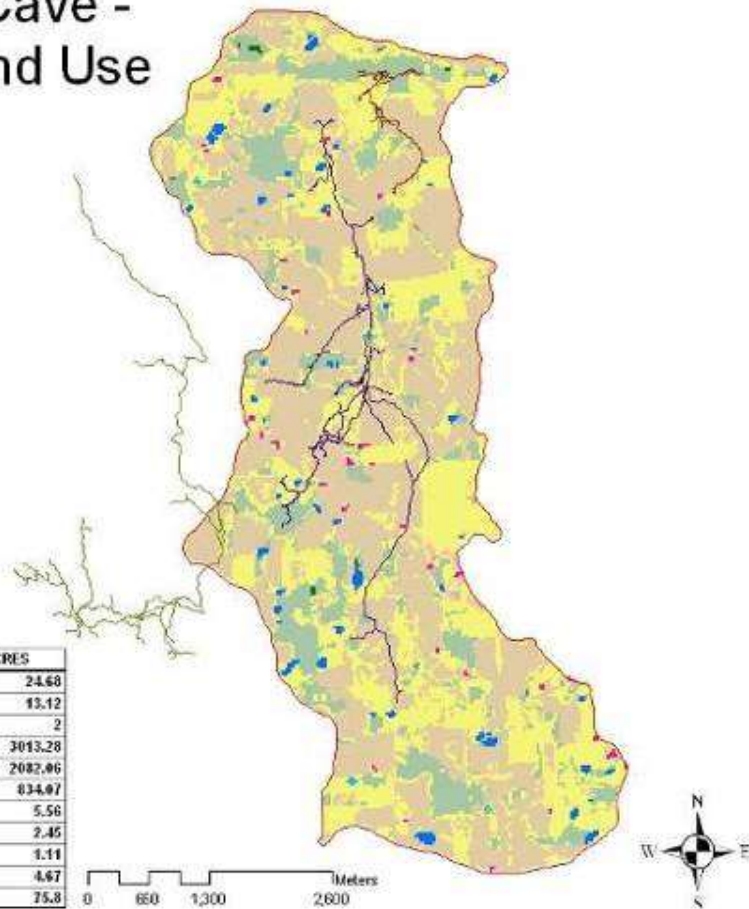


Figure 3.28. Land cover/land use of Rimstone River Cave System Recharge Area.

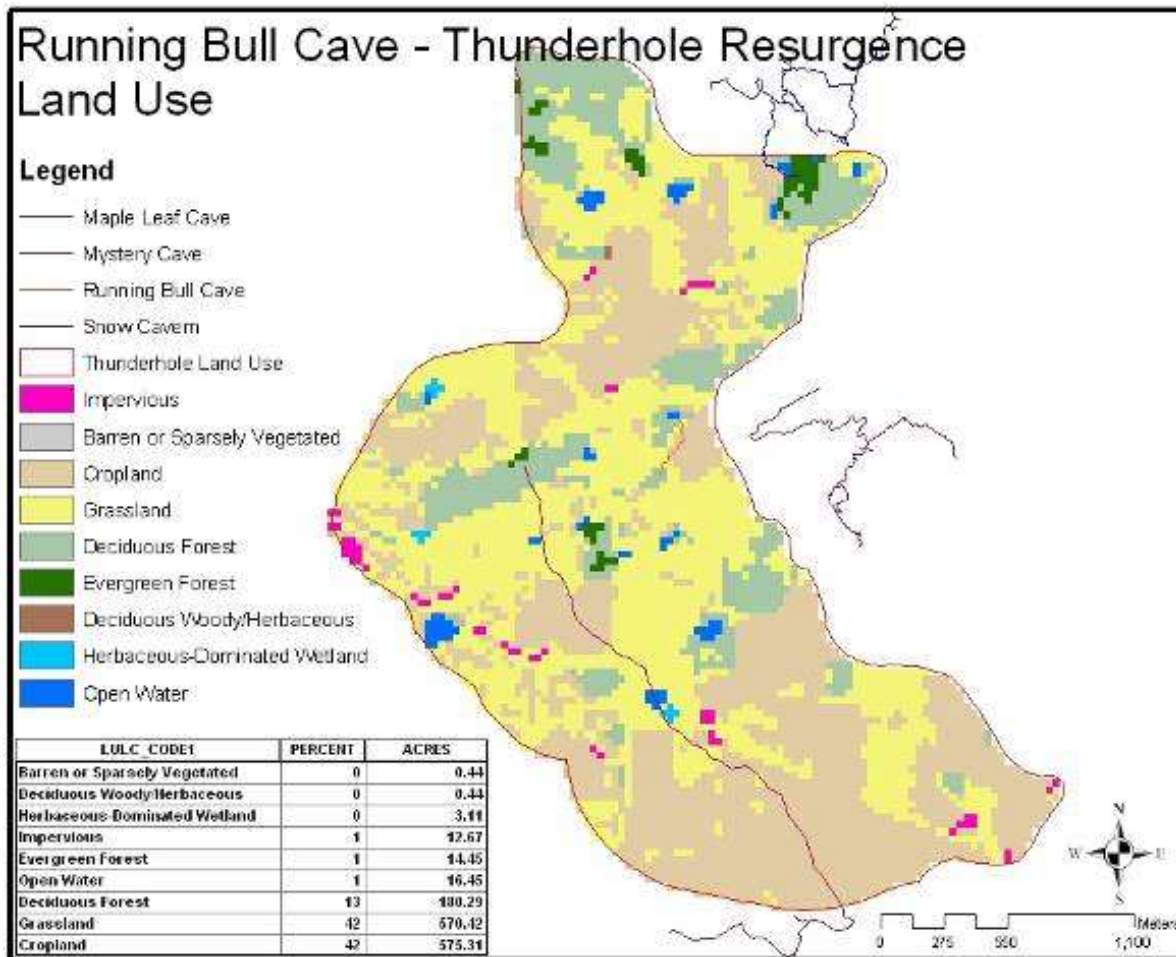


Figure 3.29. Land cover/land use of Running Bull Cave and Thunderhole Resurgence Recharge Areas.

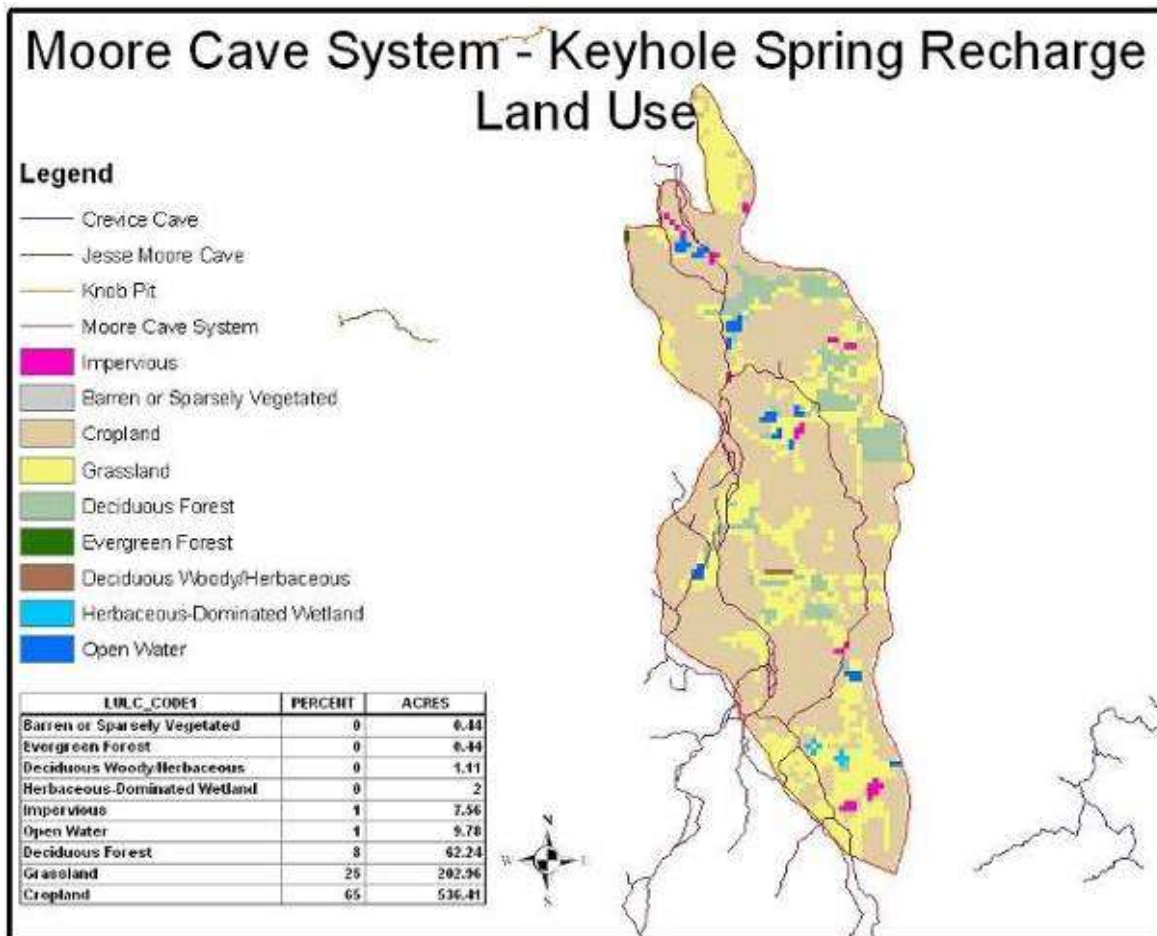


Figure 3.30. Land cover/land use of Keyhole Spring Recharge Area.

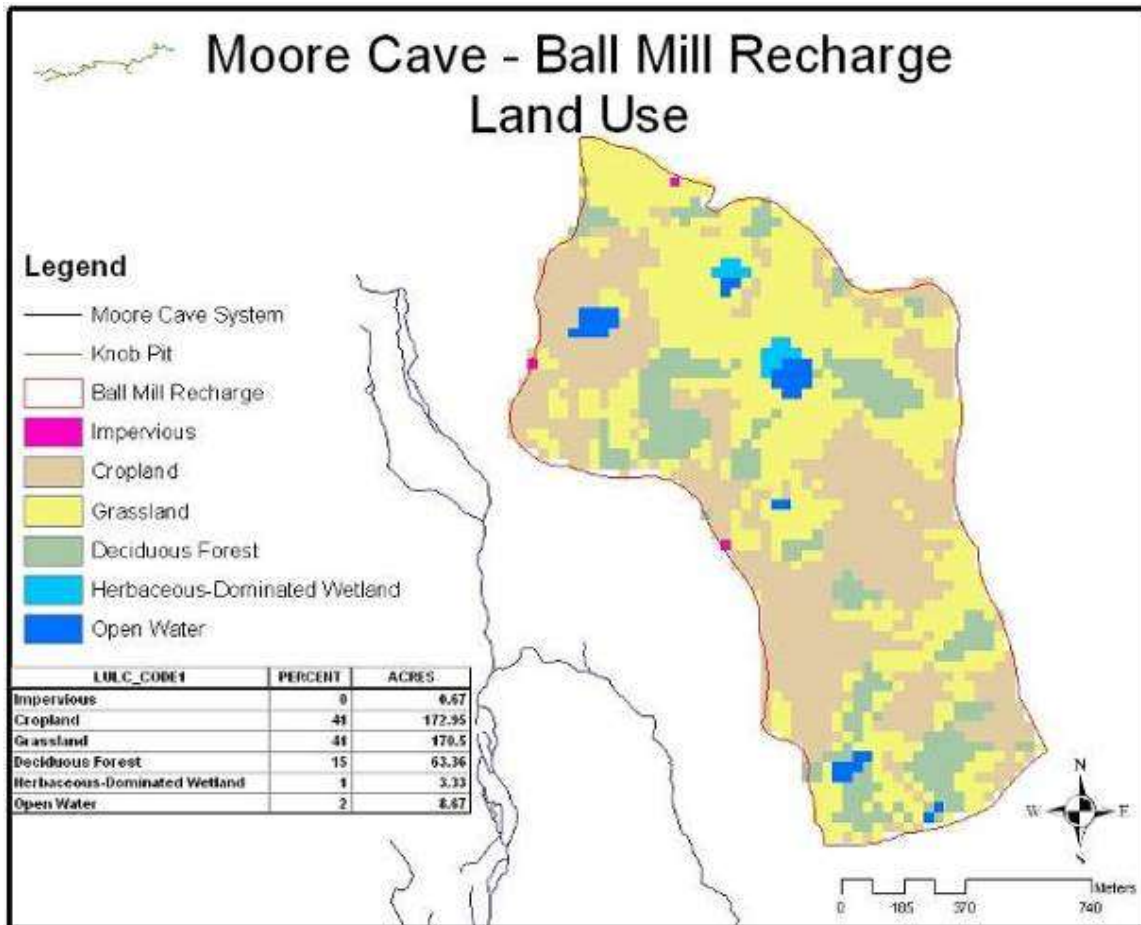


Figure 3.31. Land cover/land use of Ball Mill Spring Recharge Area.

The National Agricultural Statistics Service of the United States Department of Agriculture (USDA) conducts a Census of Agriculture every five years (www.agcensus.usda.gov; 2011). Table 3.3 illustrates the increase in acres of agricultural crops since 1987. The Farm Service Agency provided crop data for 2011 (FSA, personal communication, 2011).

Table 3.3. Acres of agricultural crops produced in Perry County from 1987 to 2012. NR=no reporting.

Crop	1987	1992	1997	2002	2007	2011	2012
Land Acres in Farms	209,452	221,634	201,396	221,854	238,893	NR	226,441
Corn	27,773	24,366	24,832	23,689	29,803	23,956	30,326
Corn Silage	919	916	868	708	810	NR	2,402
Sorghum	1,381	2,250	740	533	937	639	NR
Wheat	18,616	19,476	14,772	11,525	10,831	12,340	13,510
Soybeans	28,255	25,049	28,714	36,784	37,013	42,437	38,211
Forages/Hay	25,457	24,326	24,651	30,630	29,257	34,285	27,722
Field & Grass Seeds	NR	819	2,383	2,942	2,762	171	2,145
Vegetable & Orchard	NR	261	110	250	122	NR	333
Woodland	NR	47,355	49,678	57,924	62,113	NR	NR

The agricultural land usage is a mixture of row crop and animal production. Along with the crop data gathered in the Census of Agriculture, animal production numbers were compiled and are summarized in Table 3.4.

Table 3.4. Animal production in Perry County from 1987 to 2012. NR=no reporting.

Animal	1987	1992	1997	2002	2007	2012
Beef Cattle Inventory	13,586	12,420	13,245	14,881	35,742	38,856
Dairy Cattle Inventory	2,063	2,814	1,706	1,446	1,717	NR
Cattle & Calved Sold	20,052	19,005	18,195	21,701	22,981	26,201
Hogs & Pigs Inventory	35,150	38,955	20,212	15,007	6,939	2,580
Hogs & Pigs Sold	76,355	83,282	42,032	30,359	19,050	1,969
Sheep & Lamb Inventory	360	479	211	22	376	760
Chicken Inventory	NR	2,820	310	605	1,046	1,101
Broiler Chicken Sold	0	194	5	607	1,721	NR
Horses & Ponies	NR	NR	223	506	639	440

The numbers show a yearly increase in acres of soybeans, forages/hay and timber production and numbers of beef cattle. These increases are a result of public demand and elevated market prices. A drop in hogs and pigs inventory shows a drop in public demand and market prices. The decreases in dairy cattle and corn silage are a result in the increase market value of corn which results in higher feed prices for dairy cattle while silage production as dairy feed is reduced in order to sell the crop at grain prices. The other consideration to the increasing acreage of producing farms and woodlands for timber is a decrease in the acreage of land set aside for wildlife or enrolled in conservation programs such as Conservation Reserve Program (CRP) and Wetland Reserve Program (WRP) which saw a combined 38% decline in enrolled acres.

3.2.6 Mining

There are 67 permitted mines and quarries in the county but only 12 are currently in operation (PC 4-H GIS 2010, MDNR 2011; Figure 3.32). The permitted mines consist of seven limestone quarries, one sand quarry, one sand/gravel mine, and three in-stream gravel mines. There is currently no permitted in-stream gravel mining in the project area; however, since it is legal for landowners to remove small amounts of creek gravel for on-farm usage without a permit, there may be undocumented small, in-stream gravel mining areas throughout the county.

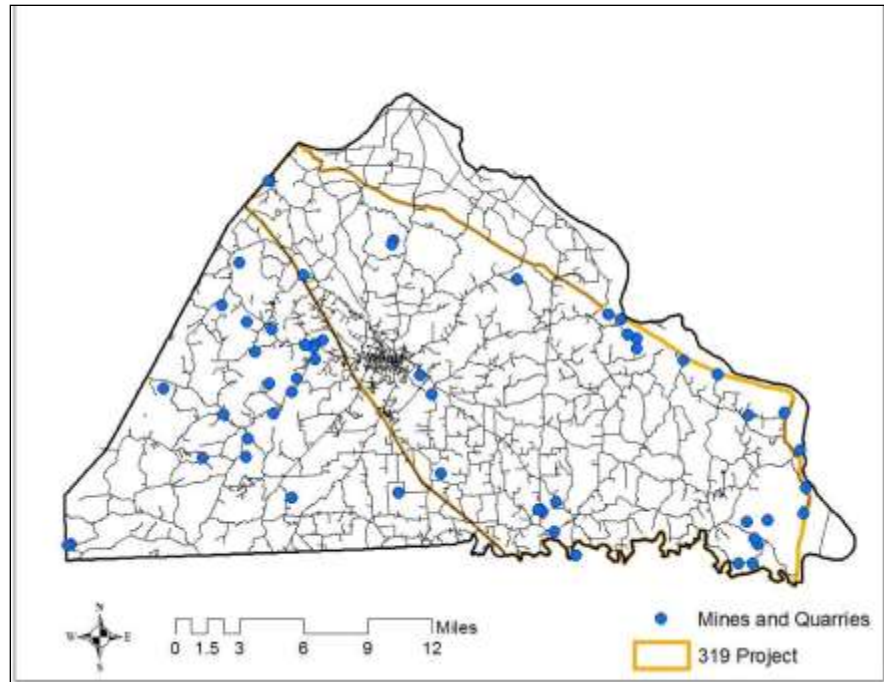


Figure 3.32. Map of mines and quarries in Perry County, Missouri.

3.2.7 Transportation

Transportation in the county consists of a highway system, one freight railroad track (35 miles) outside the project area, one municipal airport outside the project area, and one hospital heliport within the project area. The highway system consists of one interstate highway covering 21 miles, Interstate 55, two primary state highways covering 46 miles, Highway 51 and 61, several secondary lettered state highways, and numerous county roads that are predominately gravel with a few that are black-topped (CARES 2012).

3.2.8 Political Boundaries

3.2.8.1 Federal Lands

3.2.8.2 State Lands

Private individuals own the majority of the property in the county, with some ownership by companies and municipalities. There are no federal land holdings and the state, MDC, holds 1,745.6 acres divided amongst eight parcels (CARES 2012). The county has seven state listed historical sites that are held by state and local entities (MDNR 2011).

3.3 Demographic Characteristics

3.3.1 Population

3.3.2 Economics

3.3.3 Languages

The population of Perry County was 19,018 in 2012, 18,971 in 2010, and 16,648 in 1990 (Quickfacts 2013, OSEDA 2011). The population has an overall increase in spite of a slower rate increase of 4.6% between 2000 and 2010 when compared to the 8.9% increase between 1990 and 2000. The

urban populations, based on the 2000 census, is centered around: 1) three cities, Perryville (8,262), Altenburg (309), and Frohna (192); 2) one town, Longtown (76); 3) one village, Biehle (11); and the surrounding rural areas (9,877) (OSEDA 2013). The population is predominately white, 97.5%, with the remaining population consisting of Asian, African American, Hispanic, and Native American persons. The population is evenly split with 50.0% male and 50.0% female while 59.5 % of the population is between 18 and 64 years old, 24.5% under 18 and 16.0% 65 years old and over. Only 3.4% of the population speaks a language other than English at home. Of persons 25 years old and older, 82.0% have a high school diploma 13.8% have a Bachelor's of Science or higher. In 2011, 9,300 persons had nonfarm jobs emphasizing that farming is the foremost activity in the county. The mean household income was \$45,553 per year with 12.5% of the population below the poverty level (Quickfacts 2013). The major employers are three manufacturing companies, TG Missouri, Gilster-Mary Lee Corporation, TNT Plastics, Inc., three sawmills, East Perry Lumber Company, Rustic Wood Products, Inc., and Altenburg Hardwood Lumber Company, and the Perry County Memorial Hospital.

Section 4. WATERSHED ASSESSMENT AND ANALYSIS

4.1 Water Quality Standards

The main objective of the Clean Water Act of 1972 and amendments are to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Two major components of water quality standards are designated uses, and water quality criteria to protect those uses. Per federal regulations at 40 CFR §131.10, the designated uses and criteria to protect those uses assigned to a water body shall provide for the attainment and maintenance of the water quality standards of downstream waters. Missouri's Water Quality Standards regulations are found in 10 CSR 20-7.031 and are available from the Secretary of State website at www.sos.mo.gov/cmsimages/adrules/csr/current/10csr/10c20-7a.pdf.

Water quality standards provide a means by which attainment of the water quality objectives can be measured. All of Missouri's water quality management activities such as issuance and enforcement of discharge permits, inspection of wastewater and stormwater treatment facilities, providing technical assistance in wastewater or stormwater control, and providing financial assistance in building and maintaining wastewater treatment facilities, or Section 319 watershed planning, are focused on meeting water quality standards

4.1.1 Water Quality Criteria

Water quality criteria are limits on certain chemicals or conditions in a water body to protect particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements. All waters of the state are protected by the narrative (general) criteria. Excessive sedimentation and nutrient pollution may result in violations of the general criteria. A list of nine general criteria (or narrative statements) is provided in 10 CSR 20-7.031(4)(A) through (I) as follows:

- (A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses;
- (B) Waters shall be free from oil, scum, and floating debris in sufficient amounts to be unsightly or prevent full maintenance of beneficial uses;
- (C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses;
- (D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal, or aquatic life. However, acute toxicity criteria may be exceeded by permit in zones of initial dilution, and chronic toxicity criteria may be exceeded by permit in mixing zones;
- (E) Waters shall maintain a level of water quality at their confluences to downstream waters that provides for the attainment and maintenance of the water quality standards of those downstream waters, including waters of another state;
- (F) There shall be no significant human health hazard from incidental contact with the water;

- (G) There shall be no acute toxicity to livestock or wildlife watering;
- (H) Waters shall be free from physical, chemical, or hydrologic changes that would impair the natural biological community
- (I) Waters shall be free from used tires, car bodies, appliances, demolition debris, used vehicles or equipment and solid waste as defined in Missouri's Solid Waste Law, section 260.200, RSMo, except as the use of such materials is specifically permitted pursuant to section 260.200-260.247, RSMo.

The specific criteria are found in 10 CSR 20-7.031(5) and provide defined numeric thresholds for 229 water quality parameters for the protection of all waters in Missouri that are assigned designated uses. Specific numeric values for these parameters may vary depending upon the use the individual criterion is intended to protect. Specific criteria most applicable to the impaired streams addressed in this nonpoint source watershed management plan pertains to *E. coli* bacteria for the protection of recreational uses. In Missouri's Water Quality Standards at 10 CSR 20-7.031(5)(C) and Table A, specific numeric bacteria criteria are given to protect whole body and secondary contact recreation. For the streams in Perry County designated for whole body contact recreation category A, the *E. coli* count during the recreational season (April through October) shall not exceed a geometric mean of 126/100 mL. For streams designated for whole body contact category B, the applicable criterion during the recreational season is a geometric mean of 206/100 mL that cannot be exceeded.. To be protective of the secondary contact recreation designated use, the *E. coli* count during the recreational season must not exceed a geometric mean of 1,134/100 mL. Individual water body use designations are described in more detail in the following section. The numeric criteria for several of the water quality parameters collected in the Perry County Karst area are discussed later in the document.

4.1.2 Designated Uses

The Perry County Karst area contains 12 streams with unique water body IDs (see Table 4.1) that are assigned designated uses for the protection of aquatic life for warm water habitats (WWH), human health protection (HPP), irrigation (IRR), livestock and wildlife protection (LWP), two categories of whole body contact recreation (WBCR A or B) and secondary contact recreation (SCR). One stream segment of Apple Creek is also designated as a drinking water supply (DWS). Many of the streams are classified as Class P streams, meaning the stream segment maintains permanent flow even during drought periods, or Class C, meaning the stream may cease flow in dry periods, but maintain permanent pools of water that support aquatic life.

Table 4.1. Stream Classifications and Use Designations for Streams within the Perry County Karst Project Area

8 Digit HUC	Water Body ID	Water Body Name	Class	Length (miles)	Designated Uses	Legal Downstream	Legal Upstream
07140105	1779	Nations Cr.	P	4.5	WWH, HHP, IRR, LWP, SCR, WBCR-B	Mouth	15,34N,9E
	1780		C	2.0	WWH, HHP, IRR, LWP, SCR	15,34N,9E	8,34N,9E
07140105	1770	Cedar Fk.	P	3.4	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	9,35N,9E
	1771		C	1.2		9,35N,9E	16,35N,9E
07140105	1773	Goose Cr.	P	4.0	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	17,35N,10E
	1774		C	1.3		17,35N,10E	24,35N,9E

8 Digit HUC	Water Body ID	Water Body Name	Class	Length (miles)	Designated Uses	Legal Downstream	Legal Upstream
07140105	1758	Saline Cr.	P	11.0	WWH, HHP, IRR, LWP, SCR, WBC-A	Mouth	13,36N,9E
07140105	1786	McClanahan Cr.	C	6.7	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	Land Grant 00863
07140105	1782	Bois Brule Ditch	P	4.7	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	16,36N,11E
07140105	1781	Cinque Hommes Cr.	P	17.1	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	28,35N,11E
	1787		C	5.0	WWH, IRR, LWP, SCR, WBC-B	28,35N,11E	36,35N,10E
07140105	1772	Dry Fk.	C	2.3	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	22,35N,9E
	1792		C	9		Mouth	5,34N,12E
07140105	1793	Omete Cr.	P	3.5	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	15,35N,12E
	1794		C	5.7		15,35N,12E	3,34N,12E
07140105	1796	Brazeau Cr.	P	10.8	WWH, HHP, IRR, LWP, SCR, WBC-B	Mouth	17,34N,13E
07140105	1801	Apple Cr.	C	1.7	WWH, HHP, IRR, LWP, SCR, WBC-B	16,34N,10E	18,34N,10E
	1799		P	44.8	WWH, DWS, HHP, IRR, LWP, SCR, WBC-A	Mouth	21,34N,10E
0714007	2220	Whitewater R.	C	5.9	WWH, HHP, IRR, LWP, SCR, WBC-B	29,34N,9E	10,34N,8E

Other local uses may include sinkhole management and stormwater runoff. There are 24 public and community drinking water wells and several private wells. Figure 4.1 shows the location of drinking water wells in the Perryville Karst. The City of Perryville operates a drinking water treatment facility approximately five miles northwest of Perryville that utilizes water from South Fork Saline Creek (water body ID 1769). Since most of the streams are considered small (1st through 3rd order streams), irrigations are limited to a small scale and mainly involves watering small plots or gardens. Livestock production is important in the study area and there are areas where livestock are confined to limited area or else congregate (such as around areas where they are routinely fed or where minerals are provided). Some are near sinkhole drainage points or surface streams.

As part of a Section 319 NPS project, to determine if waters within the project area were meeting or at risk of not meeting their designated uses, several water quality projects were undertaken to identify areas of water quality concern as well as the general condition of the watershed. The types of waters monitored include springs/resurgence, and surface and cave streams (see figures 4.2 through 4.4). The evaluation included dye tracing to determine cave stream recharge areas, water quality testing (see table 4.3), grotto sculpin sampling and an assessment of vulnerable conditions within the watershed. Where possible, water quality data were compared to the state's numeric criteria. In the absence of numeric criteria (e.g. suspended solids, nutrients) the data was also compared to information collected at a MoDNR biological reference stream site located on Apple Creek, and/or to EPA Aggregate Nutrient Ecoregion IX Reference Conditions for the Southeastern Temperate Forested Plains and Hills (reference www.epa.gov/nutrient-policy-data/ecoregional-criteria for additional information). Project data collected from the South Fork Saline Creek, can also be compared and/or used to

supplement the water quality data collected from the U.S. Geological Surveys (USGS) monitoring site.

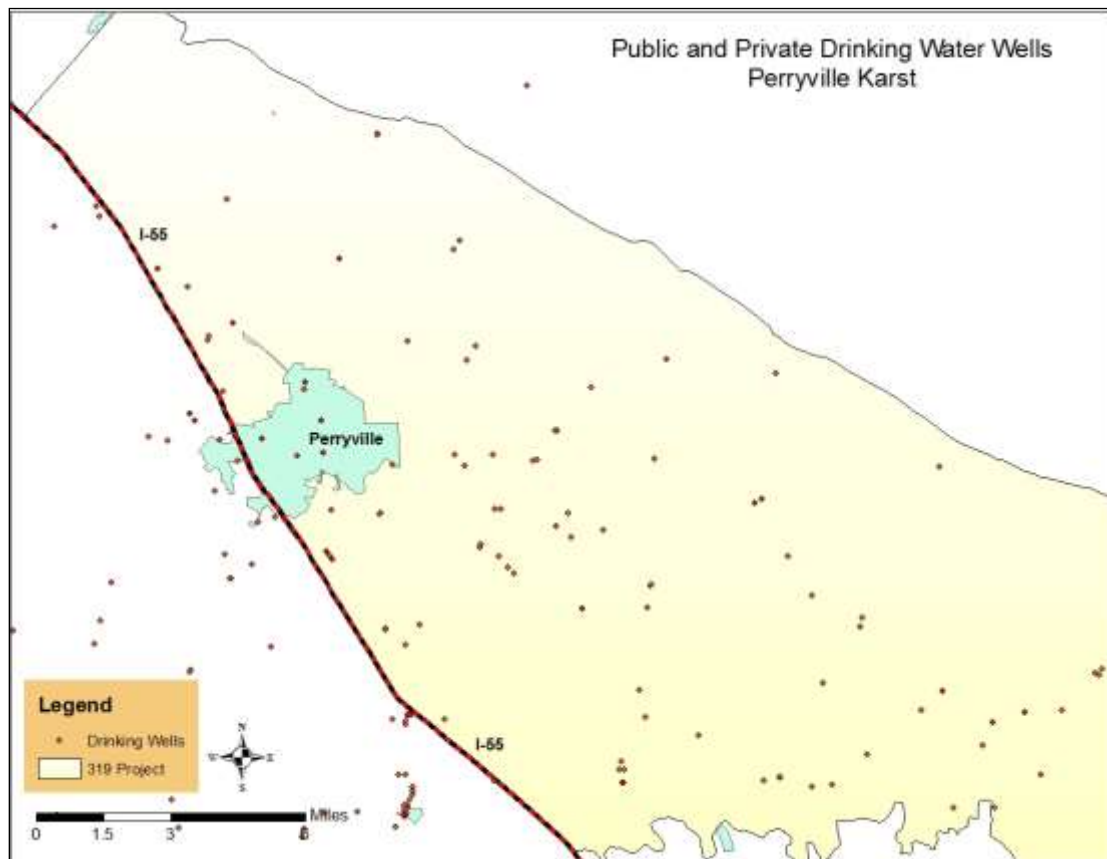


Figure 4.1. Public and Private Drinking Water Wells within the PCK project area.



Figures 4.2. Cedar Spring, 4.3. Thunderhole Resurgence, and 4.4 Cinque Hommes Creek

Table 4.2. Water Quality Parameters Collected within the PCK Project Area.

Monthly Grab Samples – Criteria Sampled	
Water Quality Parameter	Unit of Measurement
Ammonia as Nitrogen	mg/L
Chloride	ppm
Nitrate as Nitrogen	mg/L
Nitrite as Nitrogen	mg/L
Water Quality Parameter	Unit of Measurement
Ortho-Phosphate as Phosphorus	mg/L
Total Phosphorus	mg/L
<i>E.coli</i>	MPN/100mL and Geomean
Total Coliforms	MPN/100mL
Suspended Solids	mg/L
Atrazine	µg/L
Acetochlor	µg/L
Alachlor	µg/L
Deethylatrazine	µg/L
Deisopropylatrazine	µg/L
Glyphosate	µg/L
Metolachlor	µg/L
Metribuzin	µg/L
Simazine	µg/L
Continuously Monitoring Water Quality Meters (Sondes) Water Quality Parameters Sampled	
Dissolved Oxygen	mg/L
Specific Conductivity	µS/cm
pH	units
Water Temperature	Fahrenheit and/or Celsius
Water Turbidity	NTU
Cotton Samplers for Optical Brighteners	
Optical Brighteners –Fluorescence Peak	Wavelengths = nanometers (nm)

Biological Reference

The MoDNR has established biological reference stream segments located for each of the 17 ecological drainage units within the state. Biological reference streams are stream segments characterized as least impacted by anthropogenic activities (human influence) and are used to define as having attainable habitat and biological conditions. Apple Creek, contains a MoDNR biological reference segment located within the southern edge of the Perry County Karst study area. Apple Creek has been monitored seven times between 2000 and 2013. The water quality data were used as baseline conditions for the project area. Table 4.3 summarizes the data collected for the Apple Creek biological reference segment.

Table 4.3. Summary table of the water quality data collected on Apple Creek.

Year of Collection	MSCI	Flow cfs	Temp C	DO mg/L	pH pH Units	SC us/cm	NH3 mg/L	NO2-NO3 mg/L	TKN mg/L	TN mg/L	TP mg/L	Turbidity NTU	Cl mg/L	TSS mg/L
Spring 2000	14	5.4	12	13.8	8.5	306	>1.0	0.29	>1.0	--	0.04	1.58	8.93	--
Fall 2000	16	1.3	18	7.3	8.2	369	>0.05	0.06	>1.0	--	0.04	1.5	10.6	--
Spring 2001	12	12.1	10	13.9	8.17	345	--	--	--	--	--	3.8	--	--
Fall 2011	12	7.6	21	7.68	8.1	324	0.03	1.05	--	1.16	0.05	2.34	6.68	>5.0
Year of Collection	MSCI	Flow cfs	Temp C	DO mg/L	pH pH Units	SC us/cm	NH3 mg/L	NO2-NO3 mg/L	TKN mg/L	TN mg/L	TP mg/L	Turbidity NTU	Cl mg/L	TSS mg/L
Spring 2012	18	40.84	20.9	12.14	8.6	242	>0.03	0.65	--	0.82	0.04	4.85	6.29	5
Fall 2012	16	2.16	21.1	9.34	8.3	375	0.06	0.06	--	0.31	0.05	2.81	9.9	6
Spring 2013	12	28.85	7.9	14.37	8.4	257	0.03	1.48	--	1.69	0.11	7.4	8.54	>5.0
Year of Collection	MSCI	Flow cfs	Temp C	DO mg/L	pH pH Units	SC us/cm	NH3 mg/L	NO2-NO3 mg/L	TKN mg/L	TN mg/L	TP mg/L	Turbidity NTU	Cl mg/L	TSS mg/L
Low S (F)	12 (12)	5.4 (1.3)	7.9 (18)	12.14 (7.3)	8.17 (8.1)	242 (324)	>0.03 (0.03)	0.29 (0.06)	--	0.82 (0.31)	0.04 (0.04)	1.58 (1.5)	6.29 (6.68)	>5 (>5)
High S (F)	18 (16)	40.84 (7.6)	20.9 (21.1)	14.37 (9.34)	8.6 (8.3)	345 (375)	>1.0 (0.06)	1.48 (1.05)	--	1.69 (1.16)	0.11 (0.05)	7.4 (2.81)	8.93 (10.6)	5 (6)
Median S (F)	13 (16)	20.4 (2.16)	11 (21)	13.85 (7.68)	8.45 (8.2)	381.5 (369)	--	0.65 (0.06)	--	1.25 (0.73)	0.04 (0.05)	4.32 (2.34)	8.54 (9.9)	--

S=spring, F=fall; Web reference: <http://dnr.mo.gov/env/esp/Bioassessment/select-waterbody.php?water=Apple+Cr>

U.S. Geological Survey Monitoring Site

Cumulative 2009-2015	Flow (cfs)	C (C)	DO (mg/l)	pH (pH units)	SC (uS/cm)	NH3N (mg/l)	NO3N (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	Cl (mg/l)	SO4 (mg/l)	TSS (mg/l)	TDS (mg/l)
Low	4.20	0.00	5.20	6.60	165.00	0.01	0.03	0.10	0.14	0.02	2.81	4.77	15.00	144.00
High	247.00	29.90	17.70	8.40	420.00	0.05	0.52	0.82	1.20	0.10	8.34	7.98	21.00	231.00
Median	30.50	16.05	8.45	7.80	353.50	0.01	0.09	0.21	0.32	0.02	4.43	6.09	15.00	193.50
Count	42.00	42.00	42.00	42.00	42.00	42.00	42.00	30.00	40.00	42.00	14.00	14.00	42.00	14.00
Winter	Flow (cfs)	C (C)	DO (mg/l)	pH (pH units)	SC (uS/cm)	NH3N (mg/l)	NO3N (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	Cl (mg/l)	SO4 (mg/l)	TSS (mg/l)	TDS (mg/l)
Low	11.00	0.60	7.40	7.50	165.00	0.01	0.03	0.10	0.14	0.02	--	--	15.00	--
High	159.00	9.90	17.70	8.40	391.00	0.02	0.47	0.70	1.20	0.10	--	--	21.00	--
Median	34.00	4.50	14.50	7.90	306.00	0.01	0.26	0.21	0.44	0.02	--	--	15.00	--
Count	7.00	7.00	7.00	7.00	7.00	7.00	7.00	5.00	7.00	7.00	--	--	7.00	--
Spring	Flow (cfs)	C (C)	DO (mg/l)	pH (pH units)	SC (uS/cm)	NH3N (mg/l)	NO3N (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	Cl (mg/l)	SO4 (mg/l)	TSS (mg/l)	TDS (mg/l)
Low	15.00	0.00	7.90	6.60	207.00	0.01	0.06	0.16	0.22	0.02	2.82	5.47	15.00	144.00
High	247.00	25.40	14.30	8.30	388.00	0.05	0.52	0.34	0.86	0.05	8.34	7.98	15.00	226.00
Median	62.50	12.75	10.35	7.75	275.00	0.02	0.17	0.24	0.44	0.03	4.50	6.93	15.00	193.00
Count	14.00	14.00	14.00	14.00	14.00	14.00	14.00	10.00	14.00	14.00	7.00	7.00	14.00	7.00
Summer	Flow (cfs)	C (C)	DO (mg/l)	pH (pH units)	SC (uS/cm)	NH3N (mg/l)	NO3N (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	Cl (mg/l)	SO4 (mg/l)	TSS (mg/l)	TDS (mg/l)
Low	4.20	9.20	5.20	6.90	267.00	0.01	0.03	0.12	0.15	0.02	2.81	4.77	15.00	149.00
High	61.00	29.90	10.40	8.30	420.00	0.04	0.28	0.82	0.99	0.10	5.26	7.25	15.00	231.00

Median	12.00	21.90	6.80	7.80	393.00	0.01	0.04	0.16	0.26	0.02	3.34	5.57	15.00	203.00
Count	21.00	21.00	21.00	21.00	21.00	21.00	21.00	15.00	19.00	21.00	7.00	7.00	21.00	7.00

The USGS monitoring site is located on South Fork Saline Creek at Highway T and has been monitored six times per year since January 2009 for nutrients, suspended solids, and bacteria. South Fork Saline Creek is classified as a class P (permanent flowing) stream. The summary Table 4.4 provides cumulative data collected from 2009 through 2015 and then by season.

Table 4.4. Water Quality Data Collected at the USGS Monitoring Site on South Fork Saline Creek.

E. coli (colonies/100ml)	Spring	Summer	Fall	Winter
Min	2.0	2.0	7.0	2.0
Max	900	770	230	800

U.S. EPAs Aggregate Nutrient Ecoregion IX

Table 4.5 provides the EPA's Aggregate Nutrient Ecoregion IX Reference Conditions Criteria for rivers and streams (based on the 25th percentile only) as well as nutrient benchmarks for EPA Region 7 developed by the Regional Technical Assistance Group (RTAG). EPA states the ecoregion criteria are recommendations to state and authorized tribes for establishing their water quality standards. These recommended criteria are not laws or regulations; they are guidance that states and tribes may use as a starting point for criteria development for their water quality standards. Per EPA Region 7, the benchmark values developed by RTAG are consistent with the Clean Water Act and its implementing regulations at 40 CFR 131.11(a) as being protective of designated uses, are scientifically defensible, and may be used as numeric translators of narrative criteria in lieu of the ecoregional values (USEPA 2019).

Table 4.5. EPAs Aggregate Nutrients for Ecoregion IX and RTAG Region 7 Nutrient Benchmarks

Nutrient Parameter	Aggregate Nutrient Ecoregion IX Reference Conditions	Regional Technical Assistance Group Benchmarks
Total Phosphorus (TP) mg/L	0.036	0.075
Total Nitrogen (TN) mg/L	0.69	0.90
Chlorophyll a (chl a) ug/L	0.93	8.00
Periphyton chl a mg/m ²	20.35	40.00
Turbidity FTU	5.7	No value given

4.2 Available Monitoring/Resource Data

4.2.1 Water Quality Data

4.2.1.1 Pre-existing Data

Pre-existing data sets for the project area consist of small sample sizes, inconsistent locations, and restricted time frames. Due to these differences, it would be difficult to accurately draw conclusions or make recommendations on the water quality of the project area even if all the data sets were combined let alone when considered individually. The data collected during the 2008 Section 319 grant would, however, serve as a good baseline for future inferences and comparisons to be drawn upon.

Vandike (1985), while conducting a dye tracing study, collected limited water grab samples from nine springs/resurgences during the spring and summer of 1984. Vandike's water quality analysis focused on mineral content with only two components of nitrogen, nitrate+nitrite and ammonia, analyzed for nutrient pollutants. Vandike concluded that ammonia levels, ranging from 0.07 mg/L to 0.81 mg/L and with a spring average of 0.26 mg/L and a summer average of 0.04 mg/L, was considered as "...somewhat high..." for the combined five spring samples and five summer samples. Compared to recommended ammonia levels of the MoDNR reference station, (Table 4.3) these levels would be considered elevated. Vandike concluded that nitrate+nitrite levels, ranging from 0.6 mg/L to 6.4 mg/L and with a spring average of 1.4 mg/L and a summer average of 2.88 mg/L, was considered to "...reflect an abundant supply of nutrients..." for the combined five spring samples and five summer samples. When compared to recommended nitrate+nitrite levels of the MoDNR reference station these levels would be considered as elevated. Vandike considered the depressed dissolved oxygen levels to be a result of the elevated ammonia and nitrate+nitrite levels. Vandike took only five dissolved oxygen readings, ranging from 4.0 mg/L to 6.8 mg/L and with a spring average of 5.5 mg/L. While 5.5 mg/L may be considered low, the recorded spring level complies with the State minimum criterion of 5 mg/L for surface streams designated as warm water or cool water habitats. Of the targeted minerals, Vandike concluded that chloride levels, ranging from 1.5 mg/L to 69.5 mg/L and with a spring average of 27.5 mg/L and a summer average of 22.7 mg/L, was considered to be "...higher than would be expected..." for the combined eight spring samples and five summer samples. When compared to chloride levels of the MoDNR reference station these reported chloride levels would be elevated (Table 4.3 and 4.4). Vandike concluded that the widespread groundwater pollution was a result of urban runoff, rural waste disposal, and agricultural practices.

In 1994 and 1995, several fish kills were investigated by the MDC on Cinque Hommes Creek that were caused by raw sewage discharges from the Perryville Wastewater Treatment Plant. Table 4.6 summarizes water quality data collected during the fish kill investigations. The MoDNR Environmental Services personnel (1994 and 1995) concluded that the unlawful discharges caused the low dissolved oxygen and elevated ammonia levels which resulted in the subsequent fish kills.

Table 4.6. Summary of data collected during the fish kill investigation.

Date	# Fish Killed	Station	*D.O. (mg/L)	pH	Ammonia (mg/L)	*BOD (mg/L)	NFR (mg/L)
7-20-1994	65	CH above STP	9	8.0	<0.05	<6	
		Outfall at STP	6	8.0	1.3	27	
		CH 3 mi below STP	5	8.0	1.9	<6	
		CH 5 mi below STP	1	7.5	0.24	<6	
		Merlin Rousseau's Bridge					
		CH 7 mi below STP	5	7.5	0.21	<6	
		PCR322 Bridge					
8-1-1995	761	CH above STP	8.0	9.0	0.59	<2	27
		CH 75 ft below STP	5.0	7.5	0.96	110	40
		CH 740 ft below STP	3.0	6.5	1.08	120	35
		CH 2.5 mi below STP	1.0	7.5	0.13	7	11
		CH 4.5 mi below STP	2.0	7.5	0.38	<4	5
		CH 6 mi below STP	5.0	8.0	0.14	<2	80
8-28-1995	0	CH above STP	9	8.0	0.4		
		CH 75 ft below STP	5	8.0	3.0+		
		CH 740 ft below STP	2	7.5-8.0	2.8		

	CH 3 mil below STP	4	7.5-8.0	2.7		
	Merlin Rousseau's Bridge	7.5	7.5	0.8		
*Dissolved Oxygen and Biological Oxygen Demand are denoted as D.O. and BOD respectively. CH = Cinque Hommes Creek; STP = Perryville Wastewater Treatment Plant; NFR = Non Filterable Residue						

Taylor *et al.* (2000) surveyed karst groundwater in Illinois and southeastern Missouri. The data from this survey demonstrated that elevated bacterial counts are common in the study area. Moss and Pobst (2010) took their data a step farther creating fecal coliform to fecal streptococcus ratios and used those numbers to interpret whether the dominate source of the fecal bacteria were from humans, livestock, or wildlife. If groundwater quality in the study area is to be protected both human and animal wastes must receive adequate treatment. Addressing only one source of the waste is to address only part of the problem. In many cases the high fecal bacterial loads reported in the 2008 Section 319 grant found in the karst groundwater supplies were a mixture of both human and animal wastes and it is often difficult to determine which type of waste predominates. Table 4.7 shows the fecal coliform and fecal streptococcus data.

Table 4.7. Selected Fecal Coliform and Fecal Streptococcus Data.

Location	Fecal Coliform (FC, CFU/100mL)	Fecal Streptococcus (FS, CFU/100mL)	FC/FS	Interpreted Source
Echo Pit (Crevice Cave)	364	312	1.2	mixed
Keyhole Spring	228	288	0.8	mixed
Maple Leaf Cave	352	512	0.7	mixed
Maple Leaf Cave	870	156	5.6	human
Mertz Cave	248	556	0.4	livestock
Mertz Cave	300	468	0.6	mostly livestock
Running Bull Cave	4,184	1,304	3.2	mostly human
Running Bull Cave	444	480	0.9	mixed
Cinque Hommes Creek	76	186	0.4	livestock
Cinque Hommes Creek	44	464	0.1	livestock/wildlife

4.2.1.2 Section 319 Grant Data

Continuously Monitoring Water Quality Meters (Sondes)

Water can move very quickly through the groundwater system in the project area. During several dye tracing studies, minimum travel times were calculated based upon straight-line distances between dye introduction and dye detection points. The maximum travel rate was 7,640 feet per day, the minimum was 128 feet per day, and the median value was 1,576 feet per day (Moss and Pobst 2010). The duration of dye pulses at detection stations ranged from potentially less than one day to at least 294 days after dye introduction. For this reason water quality monitoring for episodic or acute contamination events must either be frequent or continuous. Table 4.8 provides approximate gradients for base level passages in each groundwater system investigated.

Table 4.8. Groundwater System Gradients.

Groundwater System	Distance (miles)	Elevation Loss (feet)	Gradient (feet per mile)	Notes
Rimstone River Cave	5.54	115	22	Bedwell Hollow to Cedar Spring
Rimstone River Cave	1.57	25	16	Labyrinth to Cedar Spring
Crevice Cave	3.86	180	47	sinking stream near V Road to Mertz Resurgence
Crevice Cave	3.60	60	17	bottom of Echo Pit to Mertz Resurgence
Running Bull Cave	1.20	40	33	bottom of entrance to Miller Spring
Groundwater System	Distance (miles)	Elevation Loss (feet)	Gradient (feet per mile)	Notes
Mystery Cave	4.15	115	28	Mystery Spring to Mystery Resurgence
Mystery Cave	5.08	155	31	Trace 07-01 to Mystery Resurgence
Mystery Cave	4.41	150	34	Trace 07-10 to Mystery Resurgence
Moore Cave System	4.21	180	43	Balman Cave to Blue Spring
Moore Cave System	3.12	130	42	Tom Moore to Blue Spring
Keyhole Spring	2.33	155	66	Trace 07-05 to Keyhole Spring
Ball Mill Spring	0.82	100	122	Trace 07-07
Bingenheimer Spring	2.62	115	44	Trace 07-06
Bingenheimer Spring	0.92	10	11	Shrine Karst Window to spring

Continuously monitoring water quality meters were moored permanently at six cave and/or resurgence locations from March 2007 through December 2009 (Figure 4.5 through 4.7 and Table 4.9). These sites were a continuation of continuous monitoring station established in September 2006. Four of the six sites corresponded with monthly water grab sample sites. Sonde data and monthly *in situ* data were merged to ground-truth both data sets. Parameters monitored were water temperature, specific conductivity, dissolved oxygen, pH, total dissolved solids, water turbidity, nitrate, ammonia, and chloride. The parameters were selected to be consistent with data collected at reference sites by MoDNR and these parameters also provide a good perspective of overall water quality conditions. All sonde and monthly *in situ* data sets were corrected for sensor calibrations, sensor drift, sensor failure, and biofouling. Nitrate and ammonia were collected only during the growing season and limited by the life of the anion pins. Chloride were collected throughout the year but were also limited by the life of the anion pins. Nitrate, ammonia, and chloride data were considered suspect due to the unstable technology of the anion pins and could only be used for gross detection.



Figure 4.5. Blue Springs Figure



Figure 4.6. Mystery Resurgence

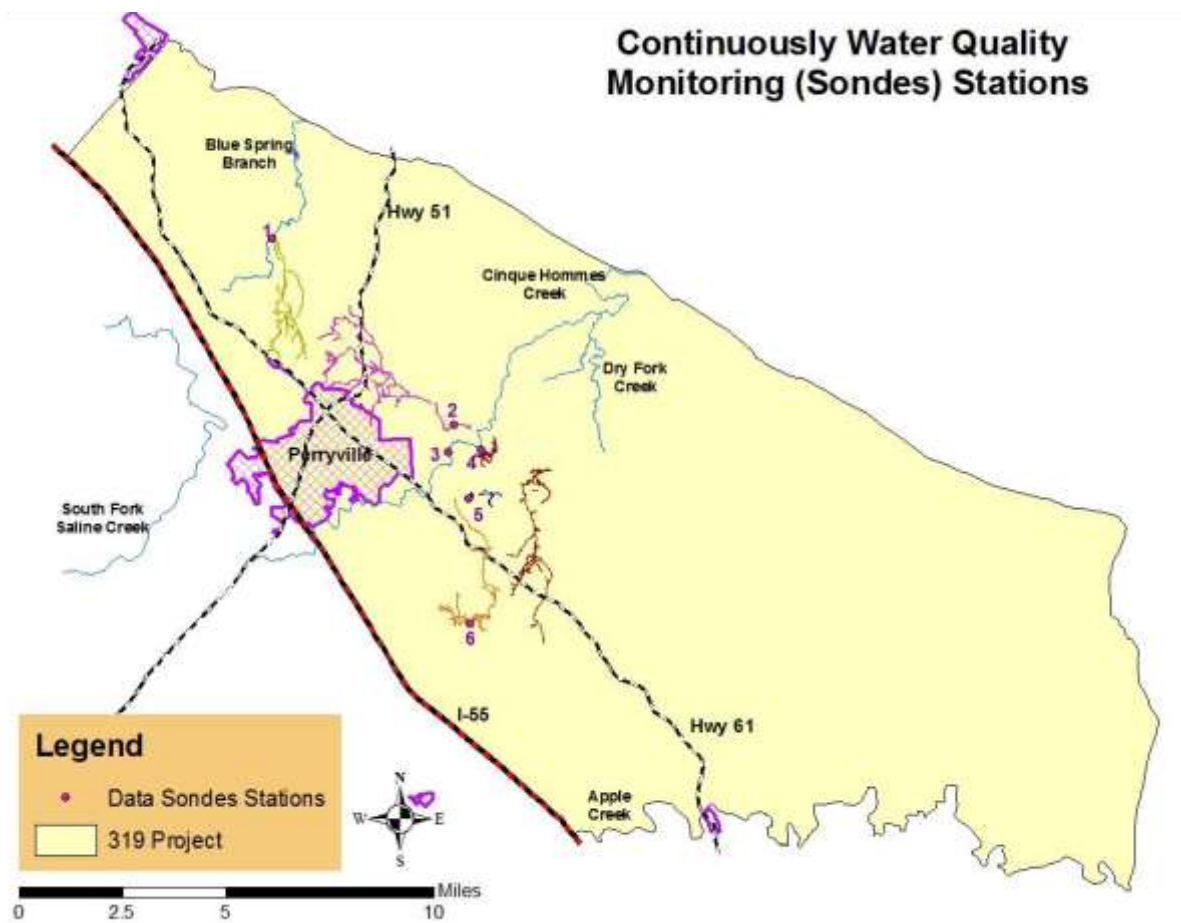


Figure 4.7. Continuous Water Quality Monitoring Sampling Stations.

Table 4.9. Continuous Sampling Sites.

Stream Name	Site #	Location
Blue Springs	1	Moore Cave System
Mertz Cave	2	Crevice Cave System
Mystery Resurgence	3	Mystery Cave System
Thunderhole Resurgence	4	Maple Leaf and Running Bull Cave
Running Bull Cave	5	Running Bull Cave Entrance
Mystery Cave	6	Mystery Cave Entrance

Rapid water movement through the cave systems results in fluctuations of water temperatures and specific conductivity during rain events. Normal water temperatures within these subsurface streams will be around 56.6 degrees F. Summer rains moving across warm surfaces can heat up quickly and in turn can quickly flow into groundwater inputs resulting in spikes in subsurface water temperatures. During rain events water temperatures can be as low as 40 degrees F and as high as 70 degrees F depending on the time of year (Figure 4.8).

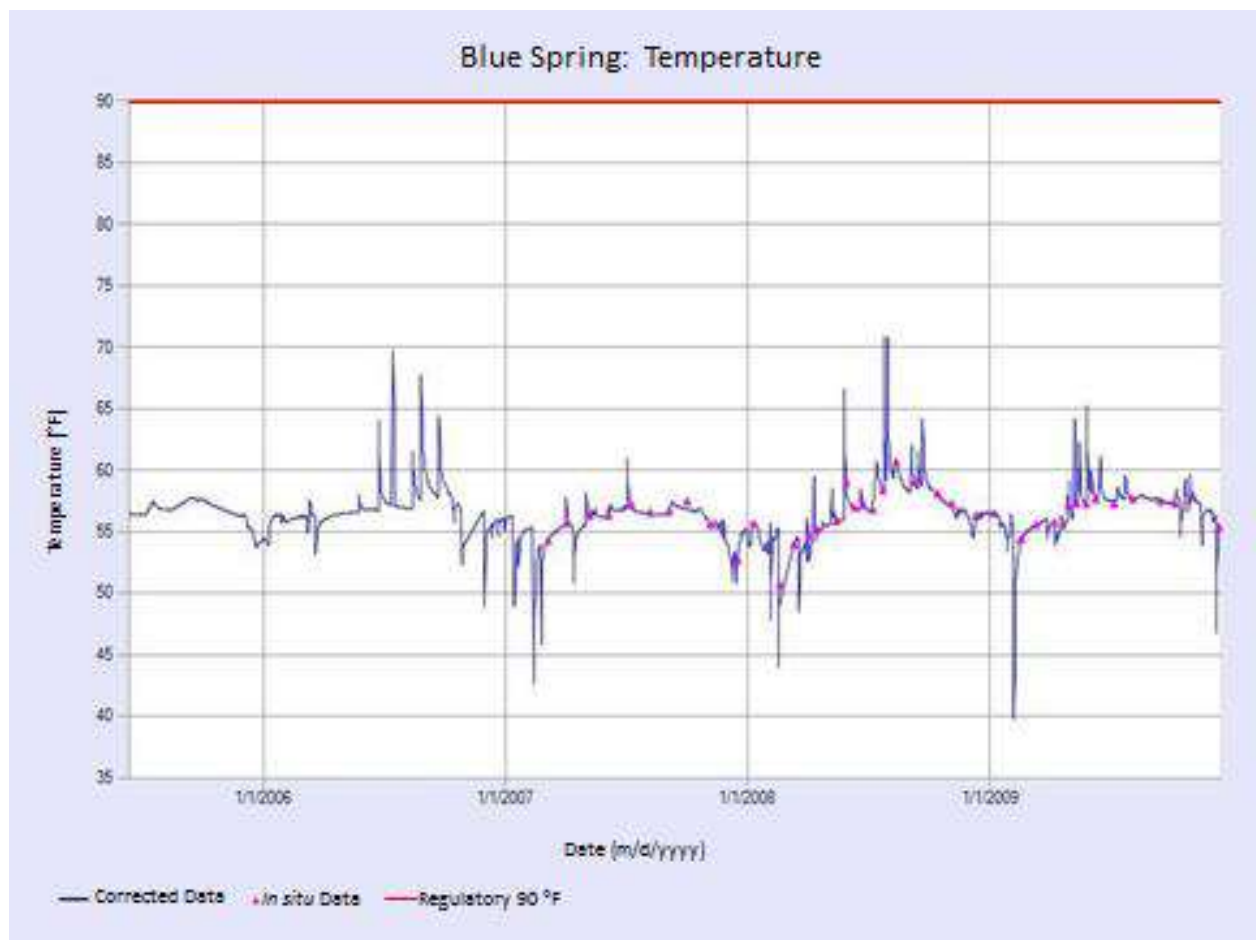


Figure 4.8. Blue Spring Temperature 2006-2009.

As this runoff is moving across the landscape, sediments are transported by the water into the subsurface streams. Specific conductivity can also be correlated to rain events and water inflow into the cave stream. Specific conductivity readings can be as low as 100 $\mu\text{S}/\text{cm}$ during runoff events, but have been documented as high as 700 $\mu\text{S}/\text{cm}$ in areas where significant influx of dissolved ions are being transported into the stream system (Figure 4.9).

Conductivity is important to aquatic organisms because it helps regulate the flow of water in and out of the organism's cells. Conductivity is the measure of how well a water can pass an electrical current. The conductivity of a stream is dependent upon the type soils and minerals natural to the area. It is often used as an indirect measure of the presence of dissolved solids (e.g. salts, nutrients, failing septic systems, nutrients, etc.). Where the presence of dissolved solids will increase the conductivity of a water. High conductivity can cause an imbalance of aquatic organisms cell regulations.

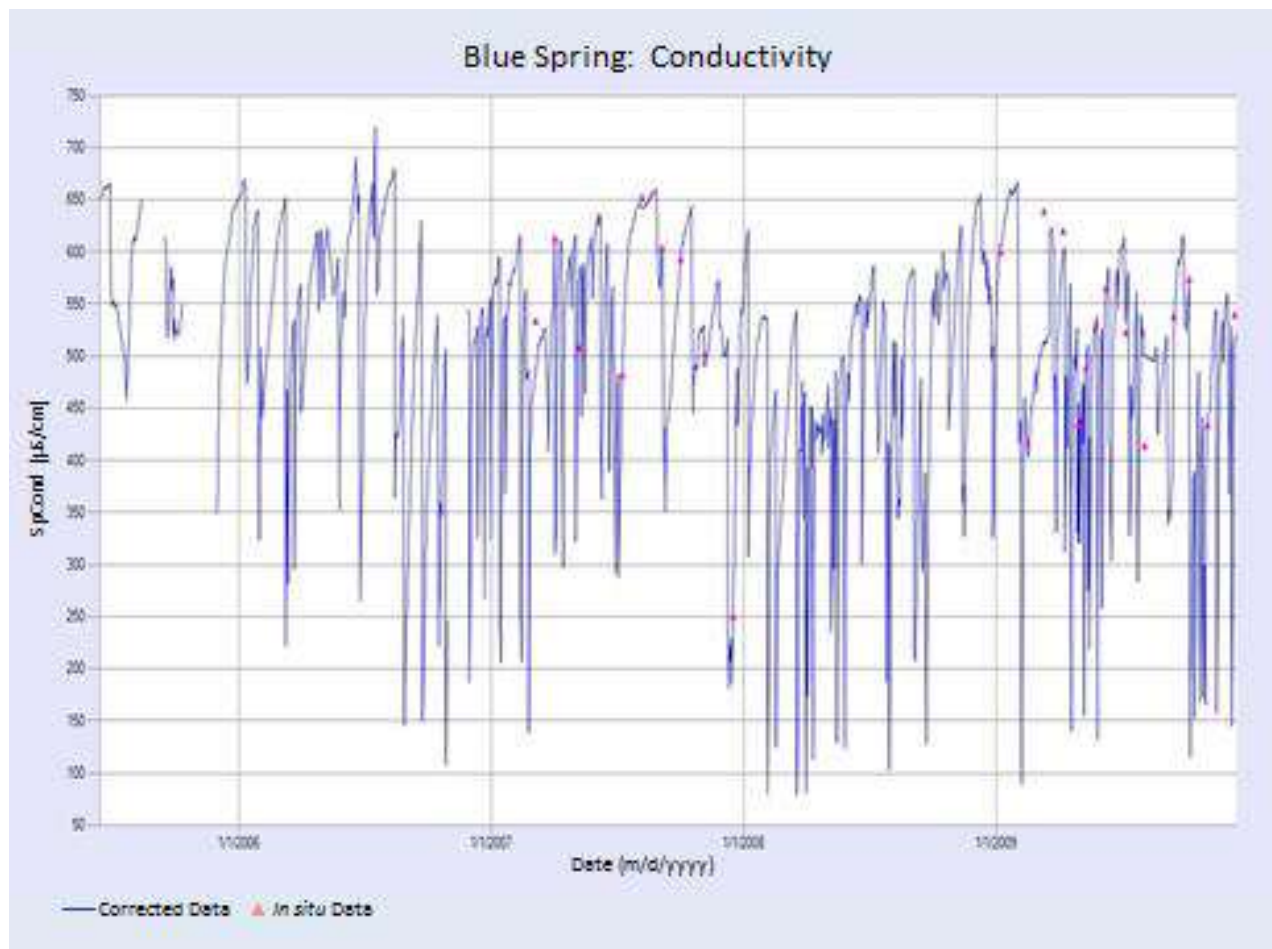


Figure 4.9. Blue Spring Specific Conductivity 2006-2009.

All plants and animals depend upon oxygen for growth and survival. Aquatic organisms also depend upon oxygen dissolved in water. Oxygen enters the water from the air, and from aquatic plants through photosynthetic processes. Dissolved oxygen is critical to the health of the aquatic community and is one of the main causes of die offs of aquatic life. Dissolved oxygen concentrations can be negatively impacted by high stream temperatures, low stream flows, excessive aquatic plants, and high amounts of dissolved or suspended solids.

The water quality criterion for streams designated as warm water or cool water habitats is a minimum dissolved oxygen concentration of 5.0 mg/L. Low dissolved oxygen concentrations have contributed to two fish kills in two different caves systems (Running Bull Cave and Mystery Cave (Fox *et al.* 2010) in the project area. Continuous monitoring at the six sites did not indicate a significant reduction in dissolved oxygen, although there were instances of oxygen readings below 5.0 mg/L. The lowest reading that was recorded was 3.5 mg/L in Running Bull Cave. There were instances where dissolved oxygen values were between 4.86 mg/L and 5.95 mg/L for up to 30 days at some sites. Dissolved oxygen concentrations below 6 mg/L for longer periods of time can stress aquatic organisms and is indicator of potential nutrient or other chemical inputs to the system. As nutrients (mainly nitrogen and phosphorus) enter waterbodies, these systems can cause significant algal growth. If significant, algal blooms can cause large 24-hour diurnal dissolved oxygen fluxuations to occur; during the day high concentrations can occur through photosynthetic activities, then during the evening and early morning hours dissolved oxygen concentrations can dip to levels below 5 mg/L when aquatic plants respiring and bacteria are consuming oxygen. During the evening and early morning hours when dissolved oxygen levels can be severely reduced for prolonged periods of time, is when stress or kills to aquatic life occur.

Each individual stream generally has a narrow range of pH values, therefore, aquatic life have adapted to these ranges. Anthropogenic (human activities) may influence the pH of surface waters. The optimal pH range for aquatic life is approximately between 6.5 and 8.2. The water quality criteria for pH is between 6.5 and 9.0. Depending upon the duration and frequency, pH values lower or greater than the standard can have a lethal effect on aquatic organisms. Of the six sites that were monitored Running Bull Cave, Mertz Cave, Mystery Entrance, Mystery Resurgence, and Thunderhole Resurgence all had pH readings below 6.5 on several occasions. These readings usually lasted from one to two days. Normal pH readings were 7.5 pH units.

Turbidity is an indicator of how much material is suspended in the water column (e.g. algae, fine sediments). The turbidity or cloudiness of the water can impact aquatic life by limiting the ability of site feeding organisms to forage. Suspended soil particles can also carry nutrients, pesticides, and other pollutants. Also because suspended particles can also trap heat from the sun, excess turbidity can cause the water to warm to above normal temperatures, which can also impact dissolved oxygen concentrations (warmer waters hold less dissolved oxygen). As suspended particles settle, they deposit along the stream bottom covering essential fish and aquatic invertebrate habitats.

Turbidity data exhibited excessively elevated values when compared to the turbidity levels collected at the MoDNR reference station (3.8 NTU) during non-runoff events. Several turbidity values often exceeded the 3,000 NTU detection limit of the sensor as illustrated in Figure 4.10. When precipitation data was compared to the continuous monitoring data a direct correlation can be seen between the two sets of data, Figure 4.11. All continuous monitoring stations exhibited the same correlations between the turbidity and precipitation data sets. It was concluded that precipitation events that produce

rainwater runoff directly causes an increase in the sediment load in surface and groundwater resources. The cave streams of the Perryville Karst sinkhole plain become very turbid during and after runoff events and stayed turbid longer than the receiving surface streams. For this reason turbidity readings are typically lower in surface streams and in the reference stream. Figure 4.12 shows the differences in turbidity when Mystery Resurgence enters Cinque Hommes Creek. Water samples were collected and analyzed for *E. coli* at all monitoring sites located with the PCK project area. *E. coli* is a common indicator species for bacteria and other pathogens. *E. coli* and other bacteria can be found naturally occurring at low levels in all surface waters. However, elevated bacteria levels are frequently associated with heavy rains or other sources (animal feeding operations, failing septic systems, etc.) that may contribute to elevated bacteria levels, which may pose a health risk. *E. coli* levels with the PCK project area ranged from less than detectable limits (2 colonies/100 mL) to 56,800 colonies/100 mL). Note that, as stated in Section 3.1.4, MoDNR has determined five streams in Perry County to be impaired due to high measurements of *E. coli*.

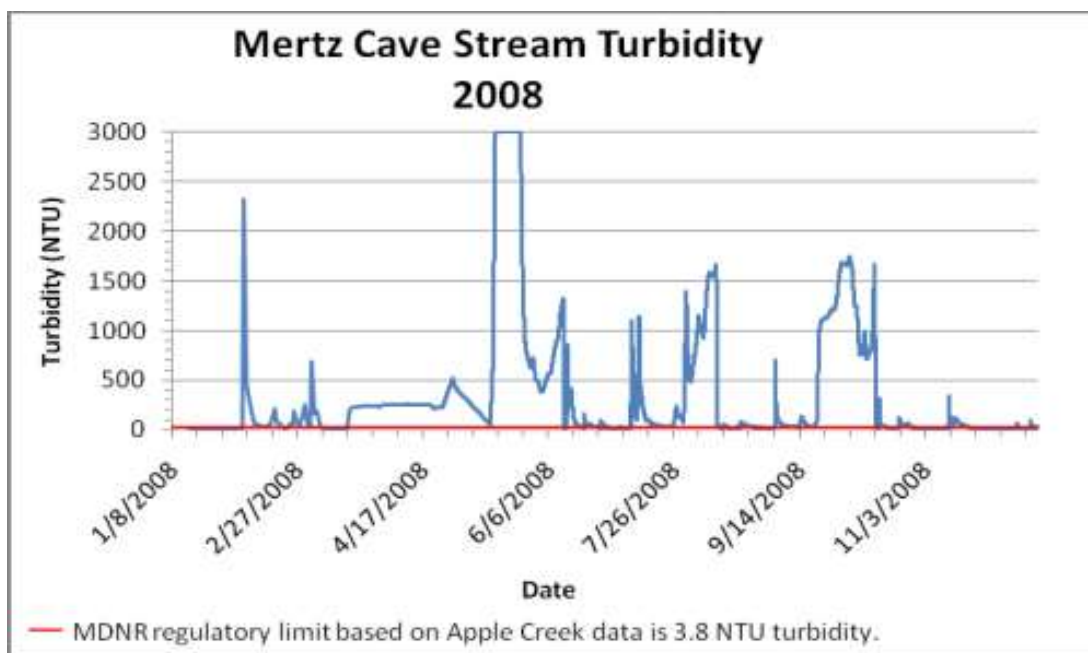


Figure 4.10. Mertz Cave Stream Turbidity in 2008.

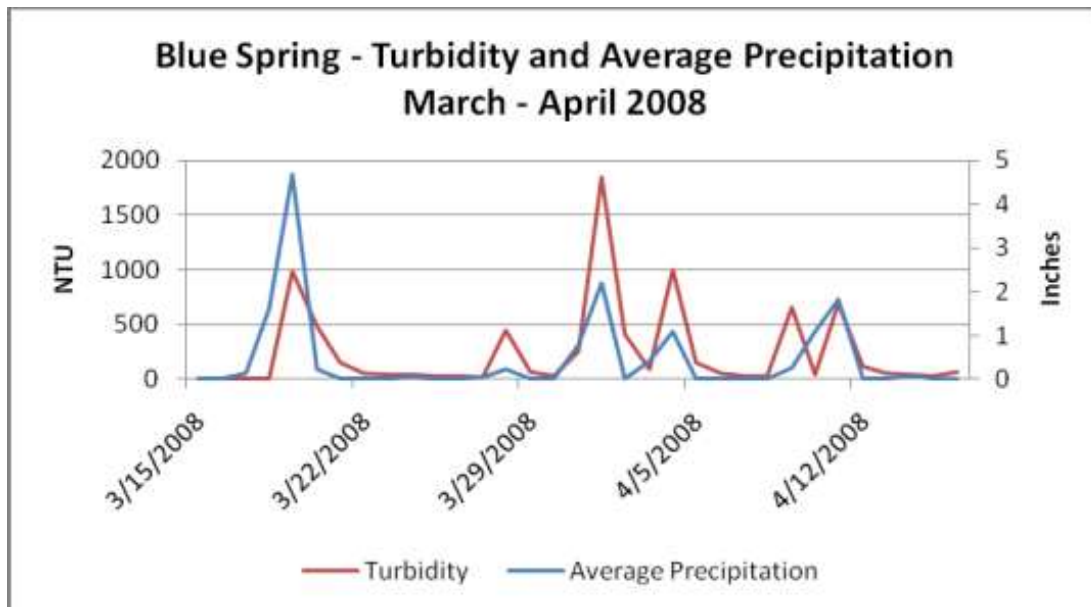


Figure 4.11. Blue Spring Turbidity and average precipitation from March –April 2008.

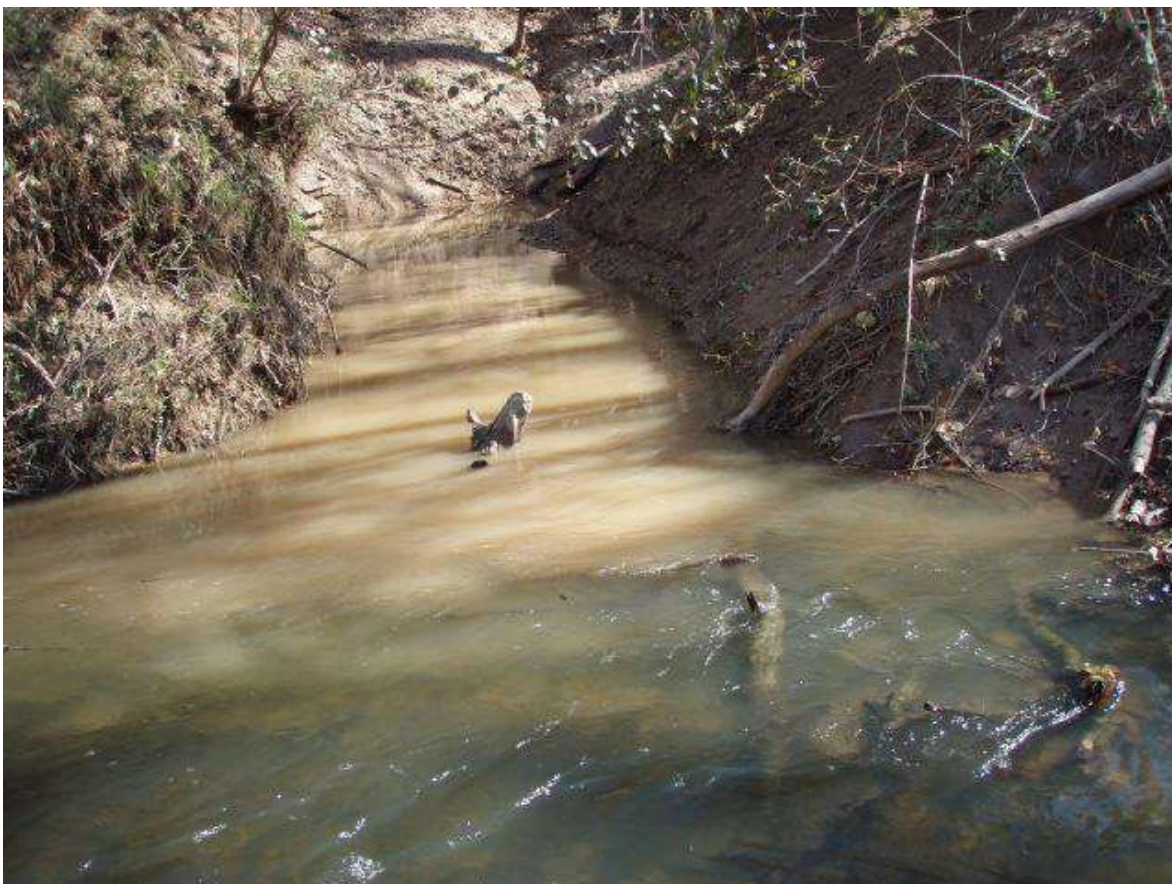


Figure 4.12. Confluence of Mystery Resurgence with Cinque Hommes Creek. Photo by Philip Moss; November 5, 2009.

Monthly Water Grab Samples

Monthly water grab samples were collected at 18 sites on the first Tuesday of each month from March 2007 to December 2009 (Figure 4.13 and Table 4.10). Two additional sites were established once sinkhole sampling started in 2010 (Keyhole and Ball Mill Spring). Sampling sites were selected based on past water quality sampling (Kraemer, personal communication 2006 and MDC 2006). All samples were analyzed for nitrate as nitrogen (NO_3^- -N), nitrite as nitrogen (NO_2^- -N), ammonia as nitrogen (NH_3 -N), chloride (Cl^-), ortho-phosphate (PO_4^{3-} -P), total phosphorus (TP), *E. coli*, total coliforms, total dissolved solids (TDS), and total suspended solids (TSS). *In situ* parameters collected at each site were temperature, pH, specific conductivity, turbidity, and dissolved oxygen. All monthly *in situ* data sets were corrected for sensor calibrations, sensor drift, sensor failure, and biofouling. Monthly herbicide samples were collected at 15 stations and analyzed for acetochlor, alachlor, atrazine, deethylatrazine, deisopropylatrazine, metolachlor, metribuzin, and simazine. Selection of analytes was based on previous water quality sampling in the project area (Vandike 1985; Taylor *et al.* 2000; Kraemer, personal communication 2006) and a review of the scientific literature dealing with karst water quality (e.g., Graening and Brown 2000; Taylor *et al.* 2000; Boyer and Alloush 2001; Panno and Kelly 2004).

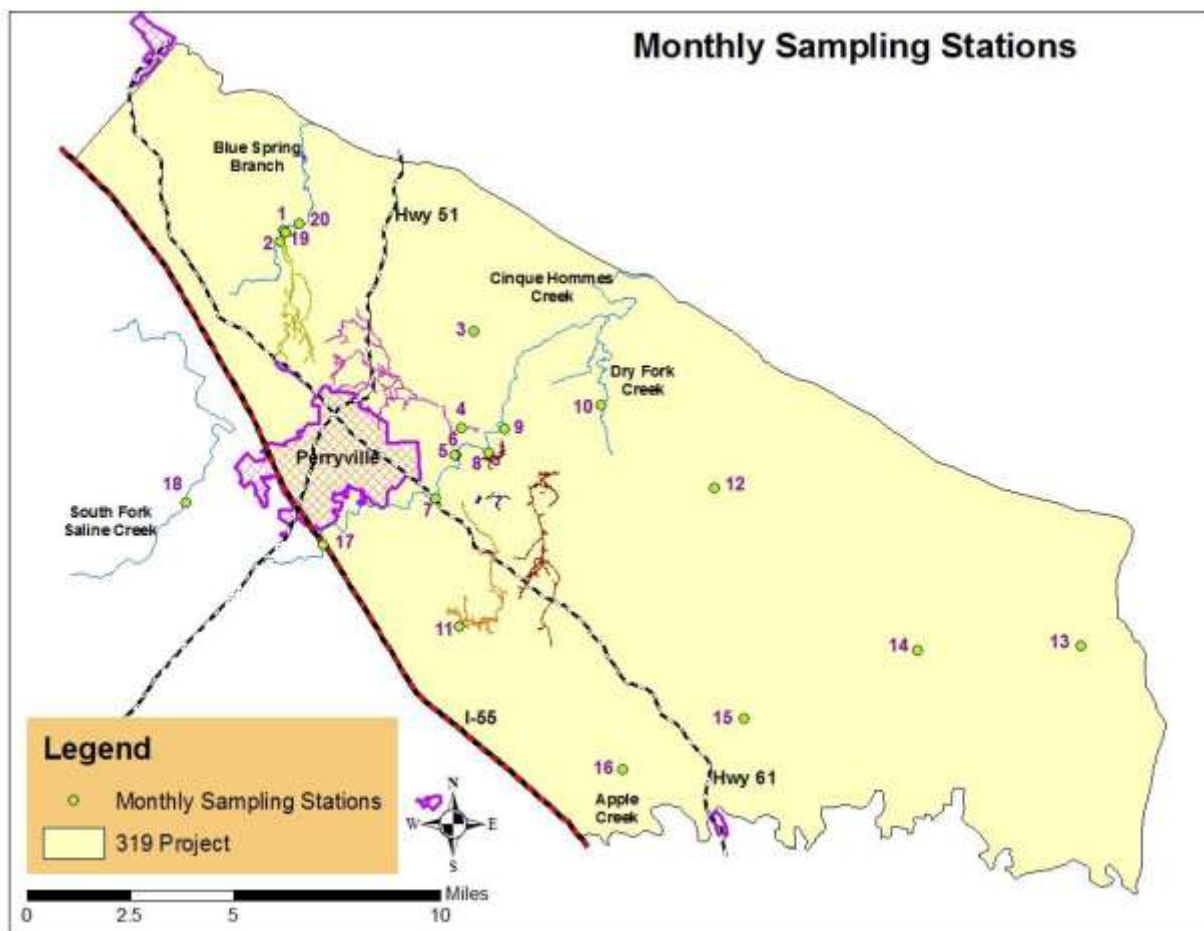


Figure 4.13. Monthly Sampling Stations.

Table 4.10. Monthly Water Sampling Sites. Note highlighted sites are listed as impaired by MoDNR.

Site description	No.	Type	Site code (DNR)	Easting	Northing	Stream or nearest stream (WBID/Classification)
Briar Spring (Buehler)	1	spring	1782/4.7/3.8/4.0/0.1	773466	4188975	Blue Spring Branch (3960*)
Blue Springs	2	spring	1782/4.7/3.8/4.3/0.1	773356	4188452	Blue Spring Branch (3960*)
Huber Branch (PCR 206)	3	stream	1786/2.2/1.0	779565	4185400	Huber Branch (3960*) Trib of McClanahan Cr.
Mertz Cave	4	spring	1781/14.5/0.5	780388	4181241	Cinque Hommes Creek (1781)
Cinque Hommes Creek (below STP)	5	stream	1781/14.9	780118	4180172	Cinque Hommes Creek (1781)
Mystery Resurgence	6	spring	1781/14.85/0.01	780165	4180215	Cinque Hommes Creek (1781)
Cinque Hommes Creek (Hwy 61)	7	stream	1781/16.5	779377	4178469	Cinque Hommes Creek (1781)
Thunderhole Resurgence	8	spring	1781/13.8/0.1	781454	4180335	trib, Cinque Hommes Ck (unclassified)
Cedar Spring	9	spring	1781/13.1	781902	4181235	trib, Cinque Hommes Ck (unclassified)
Dry Fork (Hwy P)	10	stream	1792/3.2/0.2	785861	4182089	Dry Fork (3960*)
Mystery Spring (entrance)	11	spring	1791/1.2/2.3	780133	4173560	trib, Schawanee Spring Branch (unclassified)
Omete Creek (Hwy C)	12	stream	1794/1.2/1.2	790329	4178963	Omete Creek (3960*)
Scholl's Spring	13	spring	1796/2.8/0.2	804616	4172835	Brazeau Creek (3960*)
Brazeau Creek (PCR 434)	14	stream	1797/0.1	798162	4172626	Tributary to Brazeau Creek (1797)
Indian Creek (PCR 410)	15	stream	1799/10.1/4.7	791395	4169880	Indian Creek (3960*)
Apple Creek Shrine (Shrine Karst Window)	16	spring	1799/18.9/1.1	787042	4167793	trib, Apple Creek (unclassified)
Cinque Hommes Creek (I-55)	17	stream	1787/4.5	775017	4176795	Cinque Hommes Creek (1787)
South Fork Saline Creek (PCR 702)	18	stream	1769/16.2	769630	4178338	South Fork Saline Creek (1769)
Keyhole Spring	19	spring	1782/4.7/3.8/4.1/0.1	773539	4188882	Blue Spring Branch (3960*)
Ball Mill Spring	20	spring	1782/4.7/3.8/3.3/0.1	774089	4189201	Blue Spring Branch (3960*)
*Unique water body ID (WBID) not yet assigned URL to Water Quality Standards and Stream Designated Use and Stream Classification dnr.mo.gov/mocwis_public/waterQualityStandards.Search.do						

Table 4.11 and 4.12 provides an overall summary of the monthly monitoring efforts. When reviewing the data it is important to understand seasonal differences, and duration and frequency of when elevated data values are occurring. This will provide a greater understanding on which land management practices to apply that will improve water quality concerns. It provides a snapshot in time and can be used as starting point to focus future monitoring efforts. Specific monitoring sites indicating potential water quality concerns will be discussed later within this section.

Overall, the data indicate occurrences of low pH at many sites where the pH values dipped below 6.0 pH units. While on two occasions pH value were greater than 9.0 pH units. Of the 20 sites monitored, nine sites had dissolved oxygen concentrations below 5.0 mg/L. As previously discussed total suspended solids concentrations were found to be elevated and commonly occurred during runoff events. Similar conditions were also found for *E. coli*. During the spring sampling months elevated concentrations of atrazine were also found at several monitoring sites.

Table 4.11. Summary of monthly chemical constituent values from 20 locations in the PCK watershed from 2007-2009. Categorized by 12-digit HUC.

Parameter	Site	Water Temperature (F/C)			Specific Cond (µS/cm)*			pH			D.O. (mg/L)*			TSS (mg/L)*		
Name	#	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Bois Brule Creek Watershed (HUC 12 – 071401050301)																
Briar Springs (Buehler)	1	49/9	58/14	56/13	224	730	592	6.24	8.1	7	3.67	10.5	7	5	34.8	14.7
Blue Spring	2	50.7/10.4	60.7/15.9	56.3/13.5	251	639	508	6.18	8.09	7.5	5.55	10.7	8.5	0.96	1964.4	139.4
Huber Branch **	3	40.0/4.4	81.0/27.2	59.15/15.75	366	633	526	6.84	8.91	8.08	5	18.3	11.28	1.87	450.7	35.08
Keyhole Spring ****	19	55.5/13.0	57.7/14.3	57.2/14.0	141	648	483	6.21	7.91	6.87	3.38	10.2	8.81	2.84	381.44	47.08
Ball Mill Spring ****	20	52.7/11.5	59.2/15.1	55.9/13.2	186	689	506	5.63	7.51	6.55	3.73	9.58	6.77	5	621.61	139.44
Brazeau Creek Watershed (HUC 12 - 071401050308)																
Scholl Spring	13	47.8/8.8	60.6/15.9	56/13	312	942	688	6.19	8.6	8	8.54	12.3	10	3.12	166.03	30
Brazeau Creek	14	33.2/0.7	78.0/25.6	55.97/13.32	242	791	502	6.4	8.69	7.83	6.12	16.3	10.26	5	309	26.83
Cinque Hommes Creek Watershed (HUC 12 - 071401050305)																
Mertz Cave	4	48.4/9	60.8/16	57.36/14.09	311	840	558	6.64	8.28	7.48	7.99	11.4	9.36	5	838.35	101.27
CHC*** downstream of WWTP	5	38.4/3.6	77.6/25.3	60.1/15.5	254	772	550	6.13	8.33	7.66	5.31	15.8	9.12	5	71.76	19.51
Mystery Resurgence	6	46/8	59.6/15	56.41/13.56	188	589	466	6.43	7.9	7.25	6.75	11.1	8.88	5	666.97	55.19
CHC*** at Hwy 61	7	36.7/2.6	77.6/25.3	58.99/14.71	217	461	382	6.02	8.76	7.7	6.67	18.3	6.67	5	851.8	29.96
Thunderhole Resurgence	8	46.7/8	60/22	56.12/15.68	188	647	499	6.37	8.44	7.52	8.8	10.8	9.92	5	217.22	20.56
Cedar Springs	9	47.2/8.4	59.8/15.4	56.4/14.29	198	575	273	6.74	8.26	7.45	1.22	12	7.88	6.74	237.45	42.75
Mystery Spring	11	40.3/4.6	69.6/20.9	56.15/13.28	135	691	451	6.18	8.28	7.49	3.36	11.9	8.7	8.14	827.27	67.26
CHC*** at I-55	17	38.4/3.6	86.9/3.6	63.88/20.98	195	500	372	6.58	9.01	8.2	6.74	17.1	11.84	5	103.61	8.53
Dry Fork Creek Watershed (HUC 12 - 071401050302)																
Dry Fork Creek	10	37.0/2.8	76.4/24.6	56.85/13.35	368	588	501	6.79	8.72	7.66	1.43	15.1	8.25	5	168.3	11.93
Omete Creek	12	35/1.8	82/27.7	56.94/14.19	276	627	523	5.48	9.13	7.72	4.01	14.3	10.06	5	156.06	22.68
Indian Creek Watershed (HUC 12 - 071401050402)																

Indian Creek	15	35.8/2.1	78.1/25.6	56.99/14.08	194	565	465	5.9	8.66	7.4	2.72	13.8	8.27	0.8	76.92	14.85
Middle Apple Creek Watershed (HUC 12 – 071401050403)																
Apple Creek (Shrine Karst Window)	16	47.6/8.7	60.4/15.8	55.82/13.24	152	562	414	5.97	7.71	6.82	2.72	13.8	8.27	0.8	76.92	14.85
Saline Creek Watershed (HUC 12 - 071401050113)																
SFSC***	18	41.5/5.2	81.7/27.6	60.32/15.73	152	420	313	6.19	8.97	7.89	6.74	15.2	10.71	5	23.08	3.13
*TP denotes total phosphorus; Specific Cond denotes specific conductivity, and TSS denotes total suspended solids ** denotes stream is also referenced as McClanahan Creek ***CHC denotes Cinque Hommes Creek; SFSC denotes South Fork Saline Creek ***** These two sites were added later so data represented is from 2010 and 2011																

Table 4.12. Summary of monthly chemical constituent values from 20 locations in the PCK watershed from 2007-2009. Categorized by 12-digit HUC.

Parameter	Site	Nitrate (mg/L)			TP (mg/L)*			Chloride (mg/L)			Atrazine (µg/L)			<i>E. Coli</i> (colonies/100ml)**	
Sample Site	#	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High
Bois Brule Creek Watershed (HUC 12 – 071401050301)															
Briar Springs (Buehler)	1	1.57	7.88	4.74	0.01	0.43	0.16	1.3	32.2	16.11	0.035	0.4112	0.078	6	4400
Blue Spring	2	2.9	9.72	4.87	0.08	1.99	0.31	4.4	29.2	15.78	0.022	40.0947	0.128	22	6560
Huber Branch **	3	0.91	6.94	3.98	0.05	1.6	0.31	5.71	5.71	13.9	--	--	--	--	--
Keyhole Spring *****	19	1.66	6.34	4.1	0.06	2.18	0.32	9.63	30.8	16.89	0.033	35.8148	0.21	16	447
Ball Mill Spring *****	20	1.72	6.75	4.12	0.11	1.36	0.38	--	--	--	0.017	30.306	0.083	--	--
Brazeau Creek Watershed (HUC 12 - 071401050308)															
Scholl Spring	13	0.51	4.21	1.18	0.01	0.53	0.17	4.71	74.8	30.89	--	--	--	8	33600
Brazeau Creek	14	0.55	4.89	2.91	0.02	1.04	0.17	0.7	22	14.58	0.037	13.5399	0.143	16	15200
Cinque Hommes Creek Watershed (HUC 12 - 071401050305)															
Mertz Cave	4	1.6	7.16	3.28	0.13	0.85	0.29	4.4	65.7	16.82	0.04	8.0868	0.23	20	5800
CHC*** below WWTP	5	0.15	7.68	3.25	0.22	1.71	0.85	7.19	109	35.85	--	--	--	2	9600
Mystery Resurgence	6	1.1	5.49	2.81	0.09	0.77	0.33	--	17.9	9.23	0.038	6.1635	0.259	10	5000
CHC*** at Hwy 61	7	0.08	3.08	0.61	0.01	0.67	0.08	1.61	28	12.77	--	--	--	33	16800
Thunderhole Resurgence	8	1.46	7.63	4.15	0.05	0.75	0.27	--	23.6	10.15	0.041	3.2571	0.36	2	7760
Cedar Springs	9	1.24	5.21	2.71	0.01	0.62	0.27	3.67	14.5	7.55	0.062	40.544	0.752	12	3000
Mystery Spring	11	0.33	4.06	1.44	0.23	1.58	0.59	0.67	27.3	12.41	--	--	--	29	23200

CHC*** at I-55	17	0.02	1.14	0.3	0.01	1.07	0.09	2.9	13.1	7.52	--	--	--	2	40000
Dry Fork Creek Watershed (HUC 12 - 071401050302)															
Dry Fork Creek	10	0.19	3.04	1.48	0.01	0.94	0.17	--	15.9	10.02	--	--	--	12	32000
Omete Creek Watershed (HUC 12 - 071401050304)															
Omete Creek	12	1.7	6.12	3.08	0.02	0.88	0.19	1.77	19.7	12.88	0.054	6.3208	0.175	60	38400
Indian Creek Watershed (HUC 12 - 071401050402)															
Indian Creek	15	0.88	2.93	1.8	0.01	0.68	0.13	1.08	16.7	10.2	--	--	--	8	56800
Middle Apple Creek Watershed (HUC 12 - 071401050403)															
Apple Cr. (Shrine Karst Window)	16	0.17	11.8	2.48	0.03	1.1	0.22	--	38.9	5.54	0.036	5.4018	0.169	2	8800
Saline Creek Watershed (HUC 12 - 071401050113)															
SFSC***	18	0.02	0.74	0.16	0.01	0.15	0.01	--	27.9	1.95	0.011	40.869	0.05	2	250
*TP denotes total phosphorus; Specific Cond denotes specific conductivity, and TSS denotes total suspended solids ** denotes stream is also referenced as McClanahan Creek ***CHC denotes Cinque Hommes Creek; SFSC denotes South Fork Saline Creek **** These two sites were added later so data represented is from 2010 and 2011															

Figures 4.16 through 4.19 provide the average values for select water quality parameters and how the values compare among the monthly monitoring sites. By comparing mean values, it becomes clearer which parameters and sites should be considered for follow-up monitoring and/or to begin focusing types of land management practices to address the water quality concern. The monitoring sites are grouped by 12-digit HUC and discussed in more detail later in the document.

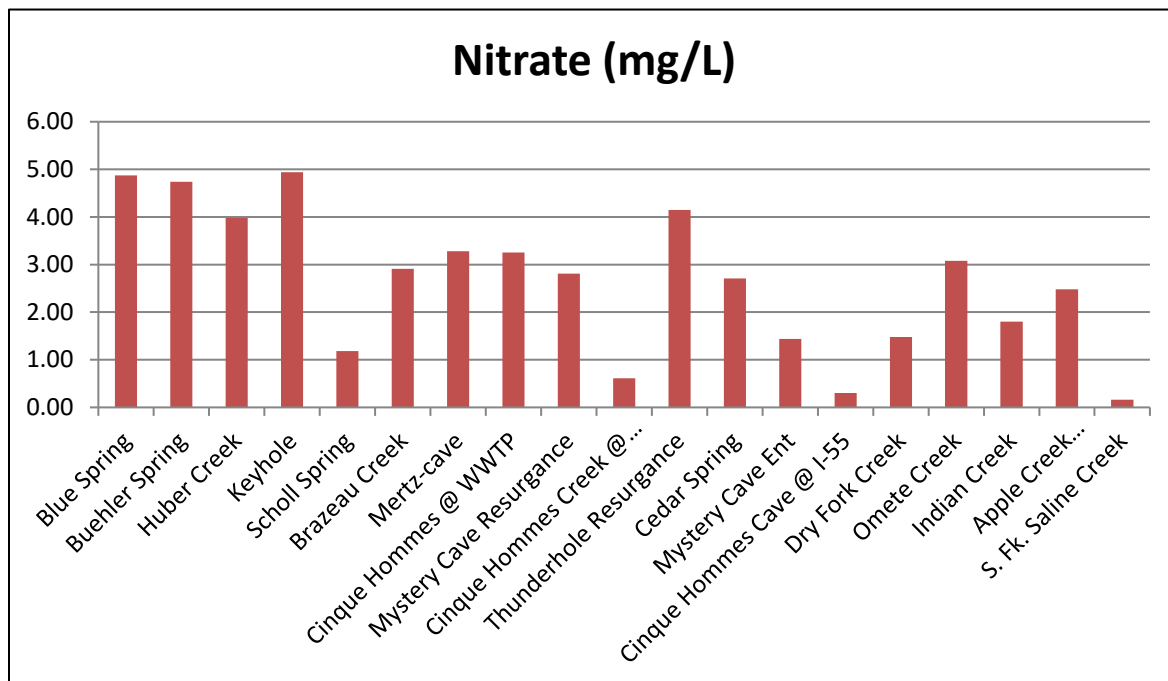


Figure 4.14. Average Nitrate as Nitrogen Concentrations for the Monthly Monitoring Sites within the PCK Project Area.

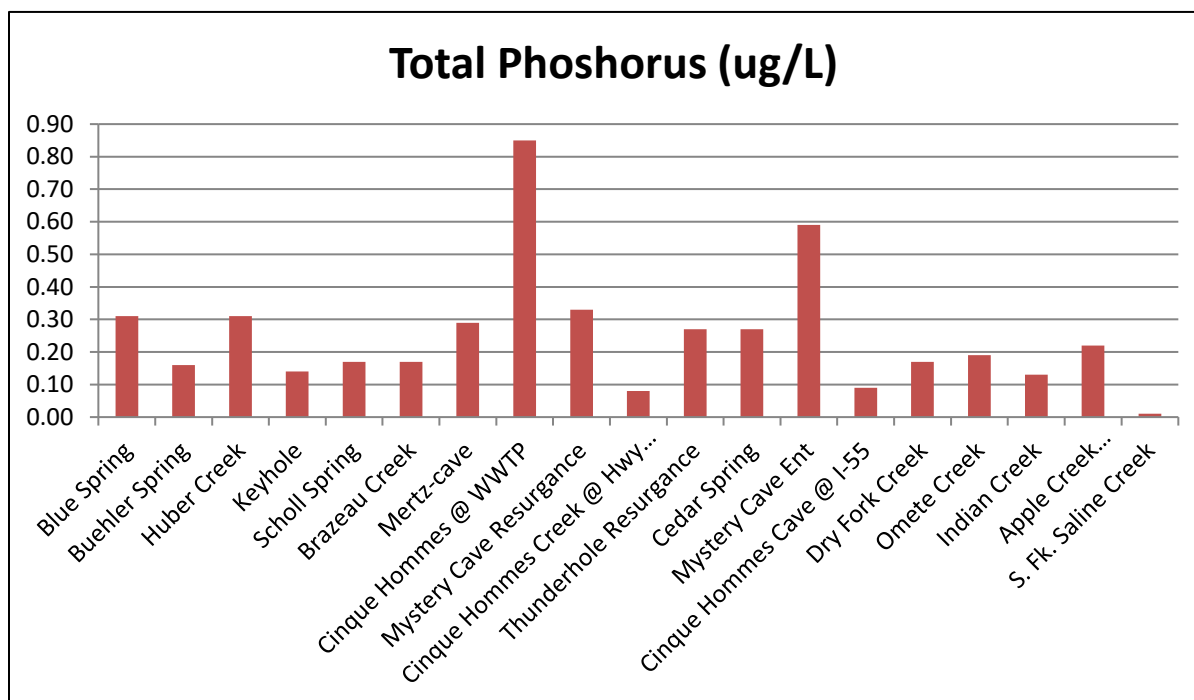


Figure 4.15. Average Total Phosphorus Concentrations for the Monthly Monitoring Sites within the PCK Project Area

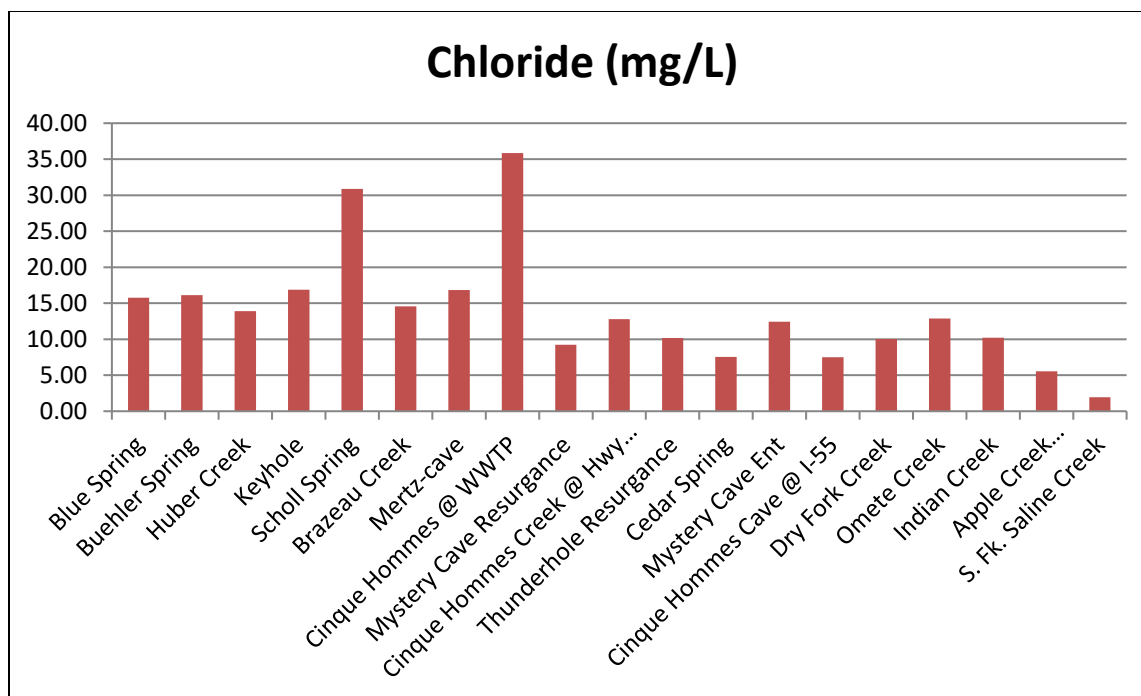


Figure 4.16. Average Chloride Concentrations for the Monthly Monitoring Sites within the PCK Project Area.

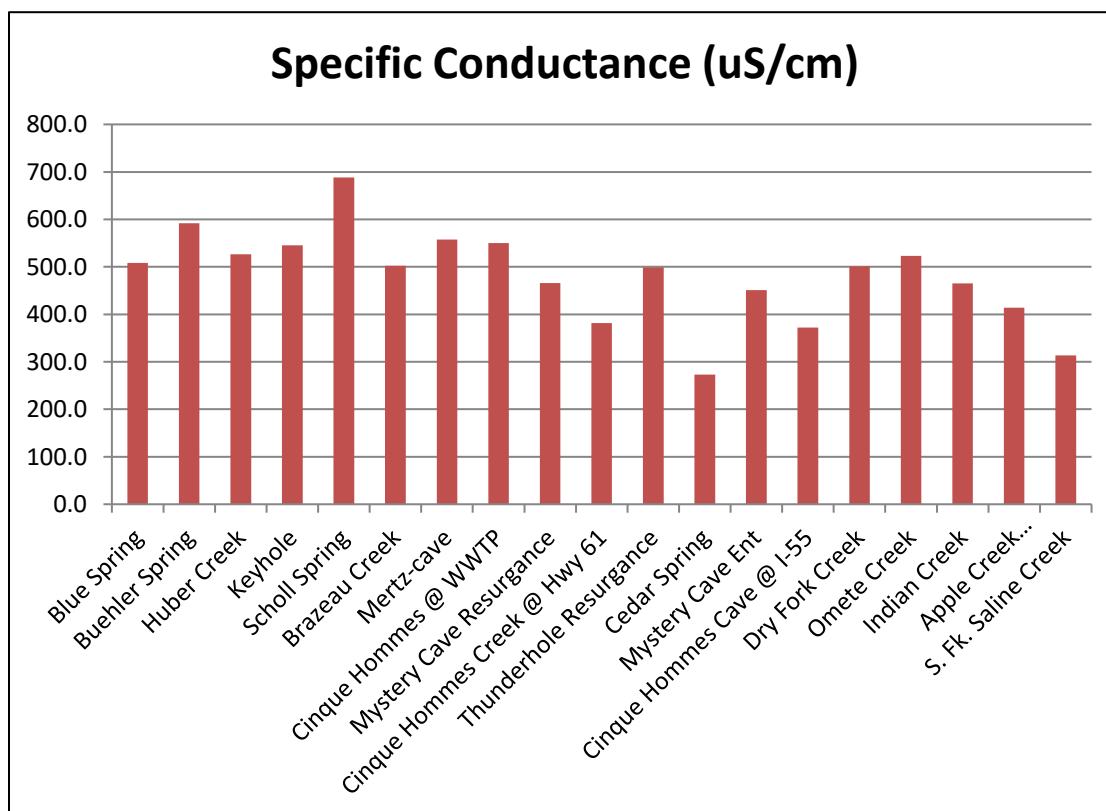


Figure 4.17. Average Specific Conductance Concentrations for the Monthly Monitoring Sites within the PCK Project Area.

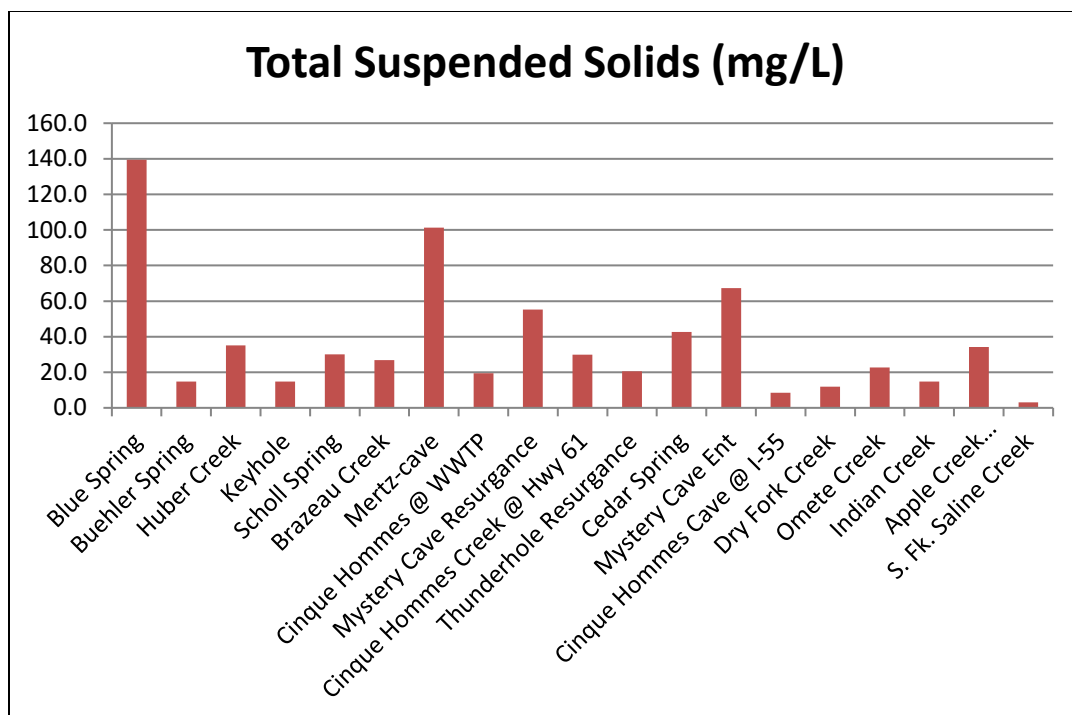


Figure 4.18. Average Total Suspended Solids for the Monthly Monitoring Sites within the PCK Project Area.

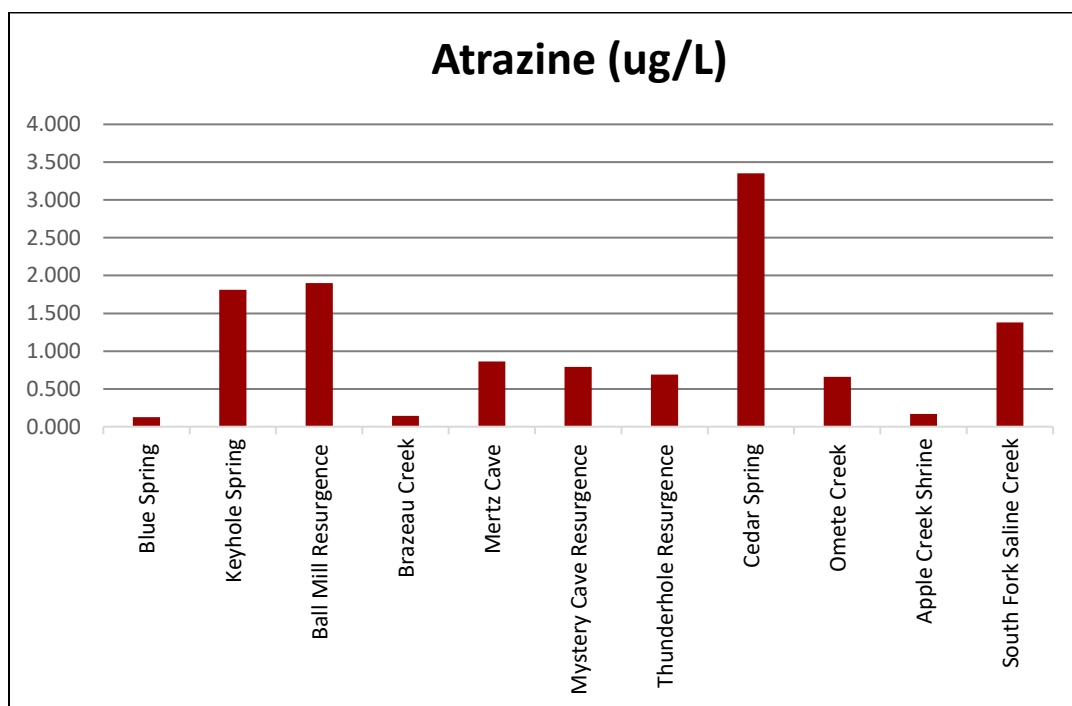


Figure 4.19. Perry County Karst Area - Water Quality Comparisons of Atrazine Concentrations.

Reviewing the data, nitrate, total phosphorus, atrazine and *E. coli* were frequently outside of the expected ranges at several sites when compared to EPA regional guidance (total phosphorus), expected ranges (atrazine), and water quality criteria (*E.coli*). A closer look at the data across seasons provides additional information on when these elevated values are occurring. The following descriptions are of each of the monthly monitoring sites sampled during the 2008 Section 319 grant. The monitoring sites are grouped by HUC 12 watershed. Seasonal evaluations

were completed to data collected during the spring (April – June), summer (July – September), fall (October – December) and winter (January – March).

Bois Brule Creek Watershed (HUC 12 – 071401050301)

The monitoring sites within the Bois Brule Creek Watershed are located northeast of the City of Perryville. Sites 1, 2, 3, and 20 (figure 4.20) are located on or flow into Blue Spring Branch. Blue Spring Branch flows in a northeast direction starting just east I-55 then flows through the City of Lithium before entering Bois Brule Creek. Huber Creek (site 3) is often times referenced as McClanahan Creek. McClanahan Creek originates east I-55 and north of Allen Landings Road where it flows in a northeast direction to Bois Brule Creek. The average concentrations for nutrients, chloride, suspended solids, and field parameters were calculated and summarized in Table 4.13.



Figure 4.20. From left to right: Site 1 (Briar Spring), Site 2 (Blue Spring), Site 3 (Huber Creek), Site 19 (Keyhole Spring), and Site 20 (Ball Mill Spring).

Table 4.13. Average Water Quality Concentrations for Monitoring Sites Located in the Bois Brule Creek Watershed.

Stream	Site Number	Nitrate mg/L	Total Phosphorus mg/L	Chloride ppm	Spec. Cond uS/cm	pH units	DO mg/L	Water Turbidity NTU	TSS mg/L
Brair/Buehler Spring	1	4.74	0.16	16.11	592	7	7	17.7	14.7
Blue Spring	2	4.87	0.310	15.78	508.40	7.50	8.50	28.13	139.40
Huber/McClanahan Creek	3	3.98	0.310	13.90	526.26	8.08	11.28	18.15	35.08
Keyhole Spring	19	4.94	0.140	16.89	545.50	7.05	8.90	10.14	14.71
Ball Mill Spring	20	4.91	0.218	--	612.64	6.99	7.29	--	18.80
Apple Creek	Ref. Stream	--	0.04	8.54	381.5	8.45	13.85	4.32	--
South Fork Saline Creek	Ref. Stream	--	0.02	4.43	353.50	7.80	8.45	--	15.00

Compared to the other waters within this Bois Brule watershed, Keyhole Spring and Ball Mill Spring had the highest average spring concentrations for atrazine at 1.8 ug/L and 1.9 ug/L, respectively, but less than the average stream concentration found in Cedar Creek located within the Cinque Homme Creek Watershed. Spikes in atrazine occurred in Blue Spring (40.092 ug/L) during the spring, Keyhole Spring (35.815 ug/L) during the summer, and Ball Mill (30.306 ug/L) during the spring. Blue and Buehler Springs had the lowest average concentrations of atrazine when compared to the all the watersheds within the PCK project area. All the waters within the Bois Brule watershed were found to have the highest average nitrate concentrations. The highest nitrate concentrations occurred in Buehler Spring (7.88 mg/L), Blue Spring (9.70 mg/L), Huber/McClanahan Creek (9.94 mg/L) during the winter season, and Keyhole and Ball Mill Springs (6.12 mg/L and 6.19 mg/L, respectively) during the spring season. Blue Spring had the highest mean TSS concentrations at 139.4 mg/L, where a 2209 mg/L TSS spike occurred during

the spring season. The lowest total phosphorus levels occurred during the summer months. The lowest dissolved oxygen levels occurred during the summer and fall months, and values fell below 5 mg/l in Buehler Spring, Blue Spring, and Ball Mill Spring.

Brazeau Creek Watershed (HUC 12 - 071401050308)

The monitoring sites within the Brazeau Creek Watershed are located southeast of Perryville and at the lower eastern corner of the PCK project area. Sites 13 and 14 (figure 4.21) are located on or flow into Brazeau Creek. Brazeau Creek (site 14) originates south of the Brazeau and flows in an easterly direction to the Mississippi River. Scholl Spring (site 13) flows into Brazeau Creek approximately a mile upstream of the confluence of Brazeau Creek and the Mississippi River. The average concentrations for nutrients, chloride, suspended sediments, and field parameters were calculated and summarized in Table 4.14.



Figure 4.21. From left to right: Site 13 (Scholl Spring), and Site 14 (Brazeau Creek).

Table 4.14. Average Water Quality Concentrations for Monitoring Sites within the Brazeau Creek Watershed.

Stream	Site Number	Nitrate mg/L	Total Phosphorus mg/L	Chloride ppm	Spec. Cond uS/cm	pH	DO mg/L	Water Turbidity NTU	TSS mg/L
Scholl Spring	13	1.18	0.17	30.89	688	8	10	23.9	30
Brazeau Creek	14	2.91	0.17	14.58	502.06	7.83	10.26	16.06	26.83
Apple Creek	Ref. Stream	--	0.04	8.54	381.5	8.45	13.85	4.32	--
South Fork Saline Creek	Ref. Stream	--	0.02	4.43	353.50	7.80	8.45	--	15.00

Compared to the other waters within the Brazeau Creek watershed, Brazeau Creek had one of the lowest average concentrations for atrazine (0.143 ug/L). The highest atrazine spike occurred in Brazeau Creek during the spring season at 1354 ug/L. Scholl Spring had the highest average specific conductance value at 827 uS/cm during the spring and 942 uS/cm during the summer months. The recreational season calculated geometric mean for *E. coli* on Brazeau Creek was greater than the applicable water quality criterion, and, therefore, this water body was placed on the states impaired waters list for bacteria (*E. coli*) due to rural nonpoint sources. When compared to Scholl Spring, the average nitrate concentration was greater for Brazeau Creek and appeared to occur throughout all seasons ranging from 40.59 mg/L during the winter and 74.77 mg/L during the fall season. The average nitrate concentrations ranged from 3.55 mg/l during the fall to 4.89 mg/L during the winter.

Cinque Hommes Creek Watershed (HUC 12 - 071401050305)

Much of the monitoring sites within the Cinque Hommes Creek Watershed are located east of Perryville and within the mid-section of the PCK project area. Sites 4, 5, 6, 7, 8 and 9 (see figures 4.22) located on or flow into Cinque Hommes Creek to the east of Highway 61, while site 17 is on Cinque Hommes Creek at I-55, and Mystery Cave entrance (site 11) is located southeast of the City of Perryville. Cinque Hommes Creek originates just west of I-55 at the confluence of Tyler Branch and Sandy Branch. Cinque Hommes Creek flows in a north easterly direction then is diverted to the southeast just north of the City of Menfro, where it flows in southeasterly direction to the Mississippi River. The average concentrations for nutrients, chloride, suspended sediments, and field parameters were calculated and summarized in Table 4.15.



Figures 4.22. From left to right: Site 4 (Mertz Cave), Site 5 (Cinque Hommes Creek below WWTP), Site 6 (Mystery Resurgence), Site 7 (Cinque Hommes Creek), Site 8 (Thunderhole Resurgence), Site 9 (Cedar Springs).

Table 4.15. Average Water Quality Concentrations for Monitoring Sites within the Cinque Hommes Creek Watershed.

Stream	Site Number	Nitrate mg/L	Total Phosphorus mg/L	Chloride ppm	Spec. Cond uS/cm	pH	DO mg/L	Water Turbidity NTU	TSS mg/L
Mertz-cave	4	3.28	0.29	16.82	557.61	7.48	9.36	39.11	101.27
Cinque Hommes @ WWTP	5	3.25	0.85	35.85	550	7.66	9.12	9.34	19.51
Mystery Cave Resurgence	6	2.81	0.33	9.23	466	7.25	8.88	32.38	55.19
Cinque Hommes Creek @ Hwy 61	7	0.61	0.08	12.77	381.82	7.7	11.21	10.27	29.96
Thunderhole Resurgence	8	4.15	0.27	10.15	498.69	7.52	9.92	20.31	20.56
Cedar Spring	9	2.71	0.27	7.55	273.39	7.45	7.88	35.09	42.75
Mystery Cave Entrance	11	1.44	0.59	12.41	450.71	7.49	8.7	42.56	67.26
Cinque Hommes Cave @ I-55	17	0.3	0.09	7.52	371.83	8.2	11.84	6.79	8.53
Apple Creek	Ref. Stream	--	0.04	8.54	381.5	8.45	13.85	4.32	--
South Fork Saline Creek	Ref. Stream	--	0.02	4.43	353.50	7.80	8.45	--	15.00

Compared to the other waters within the Cinque Hommes Creek watershed, Cedar Spring had one of the highest average concentrations for atrazine (3.354 µg/L). The highest atrazine spike occurred in Cedar Spring during the spring season at 40.54 µg/L. Cinque Hommes Creek had the highest average specific conductance value where spikes of 5668 µS/cm occurred during the summer and 5481 µS/cm during the fall months. Mertz Cave had the second highest average specific conductance where a spike of 840 µS/cm occurred during the summer months. The annual calculated geometric mean for *E. coli* on Cinque Hommes Creek was greater than the applicable water quality criterion, and, therefore, this water body was placed on the State's impaired waters list for bacteria (*E. coli*) due to rural nonpoint sources. The highest average nitrate concentration was in Thunderhole Resurgence, where the nitrate ranged from 4.80 during the spring and summer months to 7.06 and 7.63 mg/L during the fall and winter seasons. The highest average total phosphate concentrations for any of the waters within the PCK project area was in Cinque Hommes Creek at 0.85 mg/L. Total phosphorus levels in Cinque Hommes Creek were near or above 1 mg/L occurred throughout all seasons, ranging from 0.887 to 1.710 mg/L. Mystery Cave Entrance had a phosphorus spike of 1.9 mg/L and 1.35 mg/L during the fall and summer, respectively. Like total phosphorus, the highest average chloride concentrations were also noted on Cinque Hommes Creek, where the highest spikes occurred during the fall and winter months (108.7 mg/L during the summer months and 91.70 mg/L during the fall months). Mertz Cave (1984 mg/L during the summer) and Mystery Cave Entrance (827 mg/L summer) had the highest average TSS concentration of the waters located within the Cinque Hommes Creek watershed and second overall when compared to other watersheds within the PCK project area. Dissolved oxygen levels dipped below 5.0 mg/L at Cedar Spring during the fall months and Mystery Cave Entrance during the summer months.

Dry Fork Creek Watershed (HUC 12 - 071401050302)

The Dry Fork Creek Watershed is located in the mid-central section of the PCK project area, and immediately to the east of the Cinque Hommes Creek Watershed. There was only one monitoring site located within the Dry Fork Creek watershed, Dry Fork, site 10 (see figure 4.23). Dry Fork originates north east of township of Longtown. It flows in a northerly direction and enters Cinque Hommes Creek to the west of Menfro. The average concentrations for nutrients, chloride, suspended solids, and field parameters were calculated and summarized in Table 4.16.



Figure 4.23. Site 10 (Dry Fork Creek).

Table 4.16. Average Water Quality Concentrations for Monitoring Sites within the Dry Fork Creek Watershed.

Stream	Site Number	Nitrate mg/L	Total Phosphorus mg/L	Chloride ppm	Spec. Cond uS/cm	pH	DO mg/L	Water Turbidity NTU	TSS mg/L
Dry Fork Creek	10	1.48	0.17	10.02	500.56	7.66	8.25	11.88	11.93
Apple Creek	Ref. Stream	--	0.04	8.54	381.5	8.45	13.85	4.32	--
South Fork Saline Creek	Ref. Stream	--	0.02	4.43	353.50	7.80	8.45	--	15.00

Compared to the other waters within the PCK project area, the average water quality concentrations were similar to other streams and tended to be toward the lower end of the data ranges for chloride, total phosphorus, and TSS. Atrazine data was not collected for Dry Fork Creek. Dry Fork Creek experienced dissolved oxygen concentrations below 5 mg/L during the summer and fall months (1.4 mg/L and 2.7 mg/L, respectively). The recreational season calculated geometric mean for *E. coli* on Dry Fork was greater than the applicable water quality criterion, and, therefore, this waterbody was placed on the states impaired waters list for bacteria (*E. coli*) due to unknown sources.

Indian Creek Watershed (HUC 12 - 071401050402)

Indian Creek Watershed is located along the south-central portion of PCK project area. There was only one monitoring site located within the Indian Creek watershed, Indian Creek site 15 (see figure 4.24). Indian Creek originates southeast of the township of Longtown. It flows in a southeasterly direction and enters Apple Creek to the east of the township of Old Appleton. The average concentrations for nutrients, chloride, suspended sediments, and field parameters were calculated and summarized in Table 4.17.



Figure 4.24. Site 15 (Indian Creek).

Table 4.17. Average Water Quality Concentrations for Monitoring Sites within the Indian Creek Watershed.

Stream	Site Number	Nitrate mg/L	Total Phosphorus mg/L	Chloride ppm	Cond uS/cm	pH	DO mg/L	Water Turbidity NTU	TSS mg/L
Indian Creek	15	1.8	0.13	10.2	465.18	7.4	8.27	9.95	14.85
Apple Creek	Ref. Stream	--	0.04	8.54	381.5	8.45	13.85	4.32	--
South Fork Saline Creek	Ref. Stream	--	0.02	4.43	353.50	7.80	8.45	--	15.00

Compared to the other waters within the PCK project area, the average water quality concentrations were similar to other streams and tended to be toward the lower end of the data ranges for chloride, total phosphorus, and TSS. Atrazine data was not collected for Indian Creek.

Indian Creek experienced dissolved oxygen concentrations below 5 mg/L during the summer and fall months (2.6 mg/L and 3.8 mg/L, respectively).

Omete Creek Watershed (HUC 12 - 071401050304)

Omete Creek Watershed is located along the central eastern edge of the PCK project area. There was only one monitoring site located within the Omete Creek watershed, Omete Creek, site 12 (see figure 4.25). Omete Creek originates northwest of the township of Brazeau. It flows in a northeasterly direction and enters Cinque Hommes Creek near the mouth of the Mississippi River, just west of the northeastern boundary of the Red Rock Land Conservation Area. The average concentrations for nutrients, chloride, suspended sediments, and field parameters were calculated and summarized in Table 4.18.



Figure 4.25. Site 12 (Omete Creek).

Table 4.18. Average Water Quality Concentrations for Monitoring Sites within the Omete Creek Watershed.

Stream	Site Number	Nitrate mg/L	Total Phosphorus mg/L	Chloride ppm	Cond uS/cm	pH	DO mg/L	Water Turbidity NTU	TSS mg/L
Omete Creek	12	3.08	0.19	12.88	523.32	7.72	10.06	21.35	22.68
Apple Creek	Ref. Stream	--	0.04	8.54	381.5	8.45	13.85	4.32	--
South Fork Saline Creek	Ref. Stream	--	0.02	4.43	353.50	7.80	8.54	--	15.00

Compared to the other waters within the PCK project area, the average water quality concentrations were similar to other streams and tended to be toward the lower end of the data ranges for chloride, total phosphorus, and TSS. The highest atrazine spike occurred during the spring (6.321 ug/L). Dissolved oxygen dipped below 5.0 mg/L during the summer months. The recreational season calculated geometric mean for *E. coli* in Omete Creek was greater than the applicable water quality criterion, and, therefore, this waterbody was placed on the State's impaired waters list for bacteria (*E. coli*) due to unknown sources.

Middle South Fork Saline Creek Watershed (HUC 12 - 071401050109)

The Middle South Fork Saline Creek Watershed is located just west of the City of Perryville and just outside of the PCK project area. There were two monitoring sites located within the Middle South Fork Saline Creek watershed, sites 16 and 18 (see figure 4.26). North Fork Saline Creek

originates east of the township of Womack in the Mark Twain National Forest. It flows in an easterly direction towards the City of Perryville. Just to the west of Perryville the stream flows north to Saline Creek just east of I-55. The average concentrations for nutrients, chloride, suspended solids, and field parameters are calculated and summarized in Table 4.19.

Table 4.19. Average Water Quality Concentrations for Monitoring Sites within the Middle South Fork Saline Creek Watershed.

Stream	Site Number	Nitrate mg/L	Total Phosphorus mg/L	Chloride ppm	Cond uS/cm	pH	DO mg/L	Water Turbidity NTU	TSS mg/L
Apple Creek (Shrine Window)	16	2.48	0.22	5.54	413.68	6.82	8.90	20.21	34.20
S. Fk. Saline Creek	18	0.16	0.01	1.95	313.25	7.89	10.71	1.88	3.13
Apple Creek	Ref. Stream	--	0.04	8.54	381.5	8.45	13.85	4.32	--
South Fork Saline Creek	Ref. Stream	--	0.02	4.43	353.50	7.80	8.45	--	15.00



Figure 4.26. From left to right: Site 16 (Apple Creek Shrine Spring/Karst Window), Site 18 (South Fork Saline Creek).

Compared to the other waters within the PCK project area, the lowest average water quality concentrations for chloride, specific conductance, total phosphorus, nitrate and TSS were in North Fork Saline Creek. This is likely due the size of the stream at this location, which is one of the largest sites monitored. The highest spike in atrazine occurred during the summer months (40.86 ug/L). The average water quality concentrations for the Apple Creek Shrine were similar the other monitoring locations and tended to be toward the lower average concentrations. The highest atrazine spike occurred during the spring (5.402 ug/L). The highest nitrate and chloride concentrations occurred during the winter months (11.80 mg/L and 840 mg/L, respectively). The highest total phosphorus (1.1 mg/L) and TSS concentrations (840 mg/L) occurred during the spring months.

Overview of Perry County Impaired Waters

Under Section 303(d), 305(b) and 314 of the Clean Water Act each state is required to report to the EPA on the status of their state waters on April 1 every even numbered year. The information provided by the states in their 305(b) integrated report are combined into one [National Water Quality Inventory Report to Congress](#). The Missouri 305(b) Integrated Report, developed by MoDNR, provides an overview of the status of Missouri's waters. This report also includes the 303(d) List of impaired waters (waters not meeting water quality standards). The 2018 303(d) list is the most recent list approved by EPA and includes Brazeau Creek, Cinque Hommes Creek,

Dry Fork, McClanahan Creek (Huber Creek) and Omete Creek as impaired due to violations of Missouri's *E. coli* criteria. Additionally Perry County Community Lake is listed as impaired due to high concentrations of mercury in fish tissue resulting from atmospheric deposition (see Table 4.20). Although not yet approved by EPA, the draft 2020 303(d) list proposes the delisting of the mercury impairment for Perry County Community Lake, but now identifies this lake as impaired due to violations of the state's nutrient criteria.

For all waters on the 303(d) list, the state is required to develop a Total Maximum Daily Load (TMDL). TMDLs are tools to inform watershed planning. They calculate the maximum pollutant loading that a water can receive and still meet water quality standards. This loading is then allocated to various sources in the watershed and becomes the goal to restore water quality. TMDLs have not yet been developed for the impaired water bodies in Perry County. However once approved by EPA, the nonpoint source pollutant loading targets identified in any future TMDL should be incorporated into future updates of the watershed management plan. In some cases, a watershed management plan that is being implemented and can demonstrate that the pollutant reductions goals will result in attainment of water quality standards can serve as an alternative to a TMDL. In such instances, prioritization for TMDL development will be lowered and future water quality assessments will determine the effectiveness of water quality improvement efforts. Although not scheduled for TMDL development at this time, MoDNR has provided for inclusion in this plan loading targets for *E. coli* using a load duration curve approach that if met will result in attainment of water quality standards. This approach is consistent with that used for TMDL development to address this pollutant. Due to permit effluent limits and disinfection requirements, point sources are not expected to cause or contribute to the impairment and the pollutant reductions identified for nonpoint sources will result in water quality attainment. Point sources, as defined under Section 502(14) of the Clean Water Act, are regulated by MoDNR through the Missouri State Operating Permit program. For this reason, this watershed management plan and its implementation may potentially serve as an alternative to an *E. coli* TMDL for the five streams identified in Table 4-20.

Table 4.20. Waters listed on the Missouri 2018 303(d) list of impaired waters.

Year of first listing	Water Body ID	Water Body Name	Class	Water Body Size	Pollutant	Source
2012	1796	Brazeau Cr.	P	10.8 miles	<i>E. coli</i>	Rural NPS
2012	1781	Cinque Hommes Cr.	P	17.1 miles	<i>E. coli</i>	Rural NPS
2016	1792	Dry Fk.	C	3.2 miles	<i>E. coli</i>	Unknown
2016	1786	McClanahan Cr. (Huber Creek)	C	2.5 miles	<i>E. coli</i>	Unknown
2016	1794	Omete Cr.	C	1.2 miles	<i>E. coli</i>	Unknown
2016	7273	Perry County Community Lake	L3	89.0 acres	Mercury in Fish Tissue	Atmospheric Deposition

Optical Brightener Sampling

One way to test for inadequately treated sewage from on-site systems is to sample for optical brighteners. These compounds are fluorescent dyes that are part of laundry soap and detergent formulations to make clothes “whiter than white”. In properly functioning on-site sewage systems they are removed by adsorption onto soils and organic matter in the septic fields and by ultraviolet degradation and sorption onto plant matter in surface waters. If they are detected in cave or spring waters in areas lacking public sewers they indicate ineffective private sewage treatment.

Optical brightener sampling was conducted at nine locations plus a control point in the study area from March 2008 through June 2009, 110 samples. Aley and Thomson (1984) concluded that high optical brightener levels, from detergents, and high bacteria levels indicate the bacterial levels would be predominantly from human sources and a result of poorly functioning septic systems. The results were only occasional, low-level optical brightener detections at the sampled locations. However, the sampling was very limited in both time and space and should not be viewed as conclusively indicating that on-site sewage systems are functioning well in the study area. When you compare the optical brighteners to *E. coli* and total coliform sampling there is a correlation that may indicate poorly functioning septic systems in the study area.

Semipermeable Membrane Devices and Polar Organic Chemical Integrative Samplers

The SPMD and POCIS samplers were deployed at five stations that corresponded with continuously monitoring water quality and monthly water grab sample stations. Samplers were deployed in May and June of 2008 for one-month duration. Sampling sites will allow for the determination of impacts associated with urban and agricultural runoff, livestock waste, and wildlife activities in the study area. Samples were analyzed for pesticides, plasticizers, personal care products, pharmaceuticals, PAHs, wood preservatives, surfactants, and fragrances (Table 4.21 from Fox *et al.* 2010). Tables 4.22 and 4.23 summarize the results of contaminants found in the SPMD and POCIS samples.

Table 4.21. Chemicals targeted for analysis in SPMD and POCIS samplers.*

SPMD	POCIS
Pesticides	Pesticides
Aldrin	Acetochlor
Chloropyrifos	Alachlor
<i>n,n</i> -DDE	Atrazine
<i>n,n</i> -DDD	Carbaryl
<i>n,n</i> -DDT	Chloropyrifos
Diazinon	Deethylatrazine
Dieldrin	Deisopropylatrazine
Endrin	Diazinon
Heptachlor (epoxide)	Malathion
Lindane	Metalachlor
Methoxychlor	Propazine
Trifluralin	Phosmet
PAHs	Simazine
Fluranthene	Trifluralin
Phenanthrene	Plasticizers

Pyrene	Bis(2-ethylhexyl)phthalate
Plasticizers – Flame Retardants	Di- <i>n</i> -butyl phthalate
Tetra- through deca-brominated diphenyl ethers	Diethyl phthalate
Wood Preservatives	Dimethyl phthalate
Pentachloroanisole	Di- <i>n</i> -octyl phthalate
Pentachlorophenol	Others
Surfactants	Caffeine
Nonylphenol	
Fragrances	
Hexahydrohexamethylcyclopentabenzopyran (HHCB)	
Indole	
Tonalide	

*Bold face indicated analytes detected.

Table 4.22. Estimated time-weighted average concentrations (ppq, pg/L) of chemicals sequestered in SPMDs.

Analyte	Blue Spring		Cedar Spring		Mertz		Mystery		Thunderhole	
	May	June	May	June	May	June	May	June	May	June
	pg/L		pg/L		pg/L		pg/L		pg/L	
Chlorpyrifos	ND ^a	ND	5174	9340	ND	ND	ND	ND	ND	1469
Dieldrin	ND	ND	ND	ND	33914	8070	636	ND	34314	38
Heptachlor epoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	7139
Pendimethalin	ND	ND	ND	14222	9704	ND	ND	ND	ND	87720
Pentachloroanisole	707	958	ND	465	444	1336	463	442	145	292
Phenanthrene	1888	1602	2369	2699	1751	1136	939	1290	1744	ND
Pyrene	567	1151	337	ND	2432	2550	300	1117	168	212
Trans-chlordane	675	1803	ND	ND	1275	3059	ND	ND	666	1004
Trans-nonachlor	508	1365	ND	644	ND	564	ND	ND	402	1133

^a Analyte concentrations below method quantitation limits are listed as non-detections (ND)

Table 4.23. Estimated time-weighted average concentrations (ppt, ng/L) of chemicals sequestered in POCISs.

Analyte	Blue Spring		Cedar Spring		Mertz		Mystery		Thunderhole	
	May ^{(2)a}	June ⁽³⁾	May ⁽²⁾	June ⁽²⁾	May ⁽²⁾	June ⁽³⁾	May ⁽²⁾	June ⁽³⁾	May ⁽²⁾	June ⁽²⁾
	ng/L		ng/L		ng/L		ng/L		ng/L	
Acetochlor	42.6	9.9	10.3	2.9	18.4	10.2	21.3	4.8	39.8	52.6
Atrazine	60.4	22.5	60.6	123	133	74.2	69.5	30.8	84.8	87.9
DEET	2.3	5.7	2.4	2	2.5	3.4	2	2.8	3	3.5
Desethylatrazine	11.2	8.9	10.2	23	26.8	9.4	11.4	8.9	10.7	9.9
Desisopropylatrazine	ND ^c	ND	27.6	54.5	40.9	18.9	25.1	15.2	ND	ND
Diethylatrazine	4	8.7	2.1	3.9	1.7	2.7	3.4	1.8	4.2	7.8
Dimethenamid	ND	ND	5.9	39.9	5.9	2.6	ND	3.6	ND	8.9
Metolachlor	ND	6.2	10.1	9.3	4.1	12.5	2.3	5.3	2.3	2.4
Metribuzin	42.6	7.7	ND	ND	61.6	9.1	4.9	3.8	6.9	ND
Prometon	ND	ND	ND	ND	126.2	115.5	ND	ND	ND	ND
Terbutylazine	ND	ND	ND	<0.5	15.9	<0.5	<0.5	ND	ND	ND

^a number of individual POCIS composited for analysis

^b Less than (<) values are below the method quantitation limits (MQL)

^c Non-detections (ND) are below the method detection limits (MDL)

While the acetochlor, atrazine, deethylatrazine, and deisopropylatrazine concentrations in the POCIS samples were in the ng/L range, these contaminants were detected in the ug/L range for the same stations in the monthly water grab samples. Table 4.24 compares the contaminant concentrations as ug/L of the POCIS samples to the corresponding monthly water grab sample and seasonal average water grab samples. Sedimentation in the samplers was a problem during sampling periods. Petty *et al.* (2000) state that heavy biofouling can reduce the SPMD membrane's ability to uptake contaminants by as much as 69%. Alvarez (2010) stated that canisters or POCIS membranes that are covered with sediment, sample the sediment pore water instead of the targeted water column. The considerable sediment load of the project area may have prevented the uptake of contaminants by the SPMD and POCIS sampler membranes in ways that would provide representative levels. However, the SPMD and POCIS samplers successfully provided information on the presence of contaminants. While these samplers are proven effective, they seem to be less effective in waters characterized by increased turbidities and TSS levels thereby under representing the levels of contaminants present.

Table 4.24. Contaminant concentrations of POCIS samples compared to water grab samples. ND=No detection.

	Acetochlor		Atrazine		Deethylatrazine		Deisopropylatrazine		Metolachlor		Metribuzin	
	May	June	May	June	May	June	May	June	May	June	May	June
	(ug/L)		(ug/L)		(ug/L)		(ug/L)		(ug/L)		(ug/L)	
Blue Spring												
POCIS	0.04	0.01	0.06	0.02	0.01	0.01	ND	ND	ND	0.01	0.04	0.01
Grab	7.06	0.06	10.4	0.39	1.64	0.32	0.84	0.16	0.03	0.02	0.43	0.29
Cedar Spring												
POCIS	0.01	0.00	0.06	0.12	0.01	0.02	0.03	0.05	0.01	0.01	ND	ND
Grab	10.2	0.05	16.0	0.80	2.47	0.43	1.41	0.18	0.24	0.14	0.15	ND
Mertz Cave Stream												
POCIS	0.02	0.01	0.13	0.07	0.03	0.01	0.04	0.02	0.00	0.01	0.06	0.01
Grab	0.07	0.03	3.65	1.35	0.74	0.42	0.38	0.20	0.05	0.05	0.68	0.07
Mystery Resurgence												
POCIS	0.02	0.00	0.01	0.03	0.01	0.01	0.03	0.02	0.00	0.01	0.00	0.00
Grab	0.81	0.04	2.48	0.79	0.53	0.45	0.22	0.21	0.02	0.03	0.02	0.02
Thunderhole Resurgence												
POCIS	0.04	0.05	0.08	0.09	0.01	0.01	ND	ND	0.00	0.00	0.01	ND
Grab	0.75	0.03	1.66	0.20	0.45	0.18	0.21	0.11	0.03	0.02	0.06	0.01

Sinkhole and Vertical Drain Runoff Sampling

Sinkhole and vertical drain rainwater runoff samples were collected at seven stations from 2009 through 2011. Stations were limited to only seven stations due to limited number of automatic water samplers. L-A-D Foundation on the Shafer Track, allowed two fields to be cropped in order to determine the effects that agricultural practices have on surface and groundwater resources in the project area (Figure 4.27). Station trial consisted of natural sinkholes with limited to no buffers, vertical drains with no buffers, vertical drains with 25-foot buffers, and vertical drains with 50-foot buffers all in corn and soybeans. Although the natural sinkholes did have trees surrounding them, the presence of limestone terraces allowed runoff to reach the sinkhole with ease. In addition, trees at these sinkholes were in the sinkhole and up to the crest with farming practices occurring right near the edge resulting in a very limited buffer if any. Samples were collected for every rain event that produced sufficient runoff to trigger automatic water samplers. Unfortunately, the vertical drain with 25-foot buffer did not collect water resulting in no data collected for this trial. Dye traces were completed in natural sinkholes and vertical drains to determine what nearby springs received groundwater from the experimental fields. The west crop field was traced to Keyhole Spring and the east crop field was traced to Ball Mill Spring. Blue Spring was sampled due to its close proximity to the west crop field and Keyhole Spring. Water grab samples were collected each rain event, field samples were collected bi-weekly during the growing season, and monthly during the rest of the year. *In situ* parameters collected at each site were temperature, pH, specific conductivity, turbidity, and dissolved oxygen (see Table 4.19 for monthly grab samples for Keyhole and Ball Mill Spring). All monthly *in situ* data sets were corrected for sensor calibrations, sensor drift, sensor failure, and biofouling.

All samples were analyzed for nitrate (NO_3^- -N), nitrite (NO_2^- -N), ammonia (NH_3 -N), chloride (Cl^-), ortho-phosphate (PO_4^{3-} -P), total phosphorus (P_{total}), total dissolved solids (TDS), total suspended solids (TSS), acetochlor, alachlor, atrazine, deethylatrazine, deisopropylatrazine, metolachlor, metribuzin, simazine, and glyphosate. Selection of analytes remained consistent with other sub-projects of the project. Ammonia, alachlor, metolachlor, metribuzin, simazine, temperature and specific conductivity fell within water quality criteria indicating that these parameters were not negatively impacting the water quality during the sampling period in edge of field settings. However, pH and dissolved oxygen, nitrate+nitrite, total phosphorus, acetochlor, atrazine, glyphosate, turbidity, and TSS exhibited elevated levels indicating that these parameters were negatively impacting the water quality during the sampling period in edge of field settings.

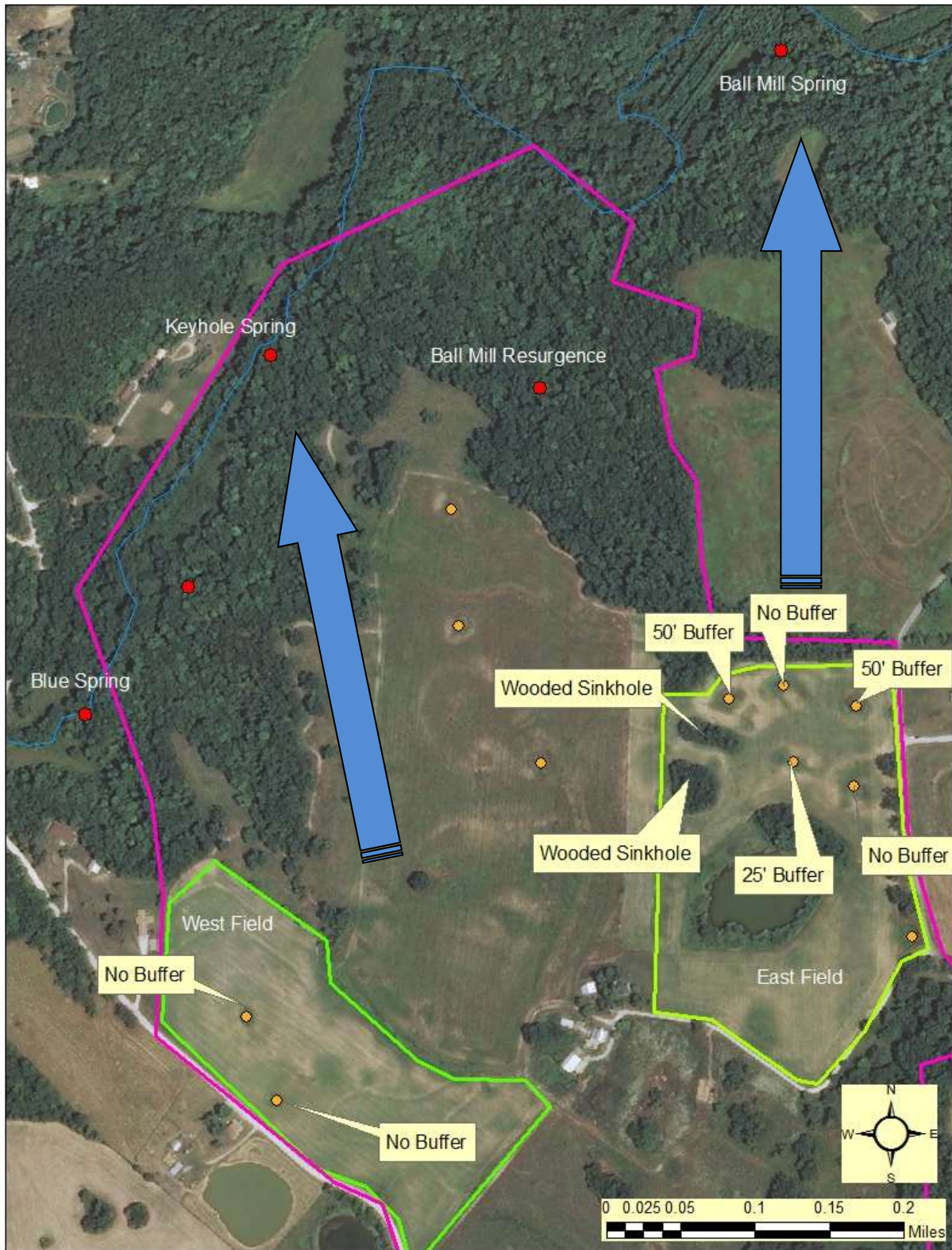


Figure 4.27. L-A-D Foundation-Shafer Track Natural Sinkholes and Vertical Drain Sampling Sites. Arrows denote groundwater movement from sinkholes in the West and East fields towards Keyhole and Ball Mill Springs.

Atrazine:

Atrazine is the dominant herbicide used in Perry County for corn and sorghum production. Atrazine is a restricted use pesticide due to ground and surface water concerns. The label for atrazine states the product must not be mixed or loaded, or used within 50 feet of all wells, including abandoned wells, drainage wells, and sinkholes. The label also states that the product is not to be used within 66 feet of where field runoff enters intermittent and perennial streams. Some products also restrict usage within 66 feet of all standpipes. The labels also state that any use of the product in an area where use is prohibited is a violation of federal law.

When compared to federal and state regulatory limits of 3 µg/L, atrazine levels were consistently elevated regardless of the trial indicating inputs were negatively impacting the water quality during the sampling period. Tables 4.25, 4.26, and 4.27 provide the high readings and dates for samples taken for all sinkholes (vertical drains and natural) on the Shafer Tract (Figure 4.27). The vertical drain with the 50 foot buffer trial may show higher levels than expected and therefore warrant further studies. The buffer was newly planted in the spring and was not well established resulting in a thin stand of grass. One third of the buffer area was inundated by sediment as a result of excessively heavy spring rains, 21 inches in 10 days in 2011. Both of these factors appear to have contributed to the reduced effectiveness of the buffer in removing contaminants from the water runoff. The wooded natural sinkhole did not have a grass buffer around the top of the sinkhole. In spite of these limiting factors, the available grass did exhibit capabilities of reducing atrazine levels from water runoff.

Vertical Drain – No Buffers: Samples were collected from September 2008 to June 2011. During this time period there were 11 excursions out of 28 ($\bar{x}$ = 88.9 µg/L). These sinkholes had more runoff events then all other sinkholes sampled. The highest reading was 227.1 µg/L taken on April 20, 2009.

Vertical Drain – 50 Foot Buffer: Samples were collected from June 2009 to June 2011. During this time period there were four excursions out of 18 ($\bar{x}$ = 26.4 µg/L). The highest reading was 63.0 µg/L taken on April 20, 2011.

Wooded Natural Sinkhole – No Buffer: Samples were collected from April 2009 to June 2011. During this time period there were five excursions out of 11 ($\bar{x}$ = 23.5 µg/L). The highest reading was 50.2 µg/L taken on April 20, 2011.

Table 4.25. Vertical Drain Sampling for Atrazine – No Buffer (High Readings).

Station	Sample Date	Concentration µg/L
1626	April 20, 2009	127
1614	April 20, 2009	227
1613	April 20, 2009	154
1626	April 28, 2009	180
1614	April 28, 2009	123
1613	April 28, 2009	92.5
1614	May 17, 2010	6.77
1626	May 17, 2010	6.14
1626	June 17, 2010	29.6
1626	June 22, 2011	27.7
1614	June 22, 2011	4.88

Table 4.26. Vertical Drain Sampling for Atrazine – 50 Foot Buffer (High Readings).

Station	Sample Date	Concentration µg/L
1614	April 20, 2011	63.0
1614	May 2, 2011	34.5
1614	May 26, 2011	3.05
1614	June 22, 2011	4.88

Table 4.27. Wooded Natural Sinkhole Sampling for Atrazine – No Buffer (High Readings).

Station	Sample Date	Concentration µg/L
374	April 20, 2011	14.3
373	April 20, 2011	50.2
374	May 2, 2011	28.5
373	May 2, 2011	19.3
373	June 22, 2011	5.00

Nitrate:

Vertical drain and natural sinkhole sampling for nitrates were consistently elevated indicating inputs were negatively impacting the water quality during the sampling period (Table 4.28). Vertical drains with no buffers had highest nitrate levels especially runoff from corn fields. The vertical drains with a 50 foot buffer and the wooded natural sinkholes without a buffer exhibited some high readings but on the average they were less than the vertical drains with no buffers. Some of these high readings were recorded after excessively heavy spring rains in May 2011; 21 inches in 10 days inundated the buffers with sediment (Figure 4.28, 4.29 and 4.30). In spite of this heavy rain event the available grass did exhibit capabilities of reducing nitrate levels from runoff.

Vertical Drain – No Buffer: 1637, 1626, 1622, 1613

Vertical Drain – 50 Foot Buffer: 1614, 373

Wooded Sinkhole – No Buffer: 374

Table 4.28. Sinkhole and Vertical Drain Sampling for Nitrates.

Sampling Station	Nitrate mg/L: Low / High / Mean (Samples)
VD 1637	Low 0.06 – High 52.69 – Mean 8.83 (12)
VD 1626	Low 0.83 – High 62.90 – Mean 22.98 (7)
VD 1622	Low 0.13 – High 9.77 – Mean 4.05 (8)
VD 1613	Low 0.02 – High 22.50 – Mean 6.46 (7)
VD 1614	Low 0.00 – High 26.90 – Mean 2.89 (12)

VD 373	Low 0.12 – High 6.18 – Mean 1.64 (5)
VD 374	Low 0.00 – High 19.00 – Mean 5.60 (5)



Figure 4.28. Vertical Drain 1613 June 2010.
2011.

Figure 4.29. Vertical Drain 1613 May

Figure 4.30. 50 foot buffer after heavy rain May 2011.

Total Phosphorus:

Vertical drain and natural sinkhole sampling for total phosphorus were consistently elevated indicating inputs were negatively impacting the water quality during the sampling period (Table

4.29). All sampling stations recorded high total phosphorus readings. Additional sampling is needed to determine buffer widths that will reduce phosphorus inputs. Receiving springs also showed elevated levels of phosphorus inputs.

Table 4.29. Sinkhole and Vertical Drain Sampling for Total Phosphorus.

Sampling Station	Total Phosphorus mg/L: Low / High / Mean (Samples)
VD 1637	Low 0.29 – High 2.14 – Mean 1.24 (12)
VD 1626	Low 0.25 – High 3.41 – Mean 1.42 (7)
VD 1622	Low 0.80 – High 2.63 – Mean 1.63 (8)
VD 1613	Low 0.19 – High 2.06 – Mean 1.45 (7)
VD 1614	Low 0.24 – High 2.71 – Mean 1.49 (12)
VD 373	Low 0.35 – High 2.33 – Mean 1.15 (5)
VD 374	Low 0.46 – High 3.31 – Mean 1.66 (5)

Total Suspended Solids:

Vertical drain and natural sinkhole sampling for total suspended solids were consistently elevated indicating inputs were negatively impacting the water quality during the sampling period (Table 4.30). All sampling stations recorded high total suspended solid readings. Additional sampling is needed to determine buffer widths that will reduce inputs. Receiving springs also showed elevated levels of total suspended solid inputs.

Table 4.30. Sinkhole and Vertical Drain Sampling for Total Suspended Solids.

Sampling Station	Total Suspended Solids mg/L: Low / High / Mean (Samples)
VD 1637	Low 33 – High 8046 – Mean 1905 (11)
VD 1626	Low 101 – High 9037 – Mean 2344 (5)
VD 1622	Low 230 – High 7775 – Mean 1901 (5)
VD 1613	Low 16 – High 3607 – Mean 574 (7)
VD 1614	Low 25 – High 2928 – Mean 578 (11)
VD 373	Low 49 – High 4225 – Mean 1121 (4)
VD 374	Low 22 – High 4878 – Mean 1241 (4)

4.2.2 Flow Data

Flow data was collected four times, once per season, at each station. Flow was taken at base flow, 0 inches of precipitation for one week. The only USGS stream gage in the project area is on South Fork of Saline Creek and is approximately two miles downstream from the monthly water grab sample station. A relationship is observed between mean discharge and average precipitation in Figure 4.31. The rapid rise and fall of South Fork Saline Creek's discharge in response to a storm event corresponds to a short-term hydrograph for streams with steeper watershed topography as opposed to streams with flatter watershed topography.

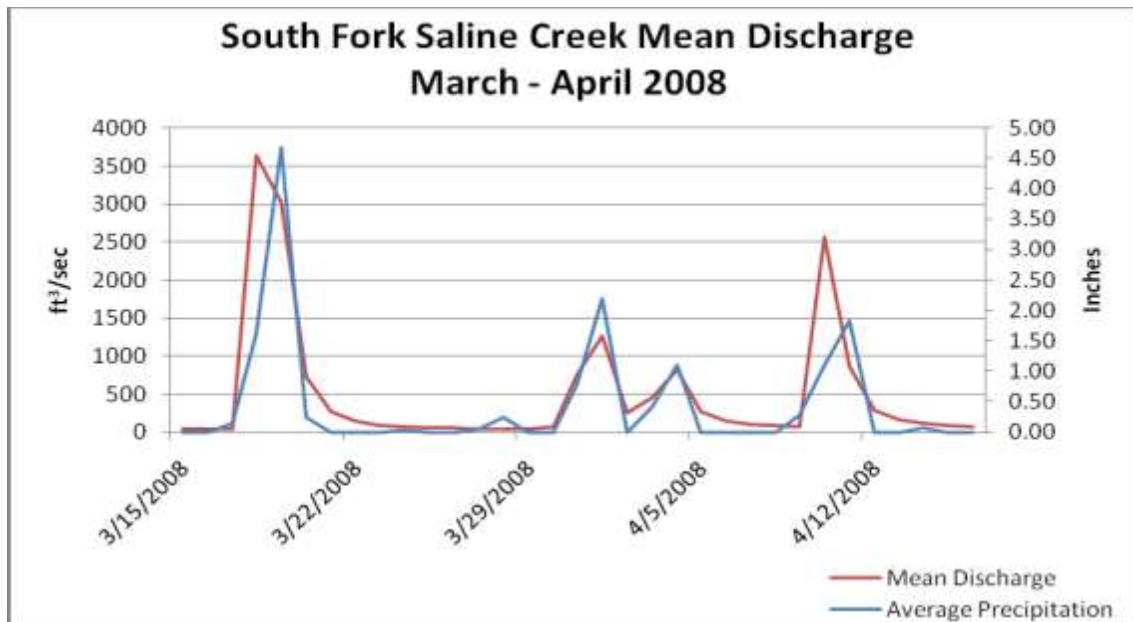


Figure 4.31. Discharge and precipitation for South Fork Saline Creek.

Eleven of the 20 stations have similar hydrographs as illustrated by Blue Spring Branch above Blue Spring (Figure 4.32a) and Mystery Cave Resurgence (Figure 4.32b). Additional years of discharge data would be needed to determine if the other eight stations (Figure 4.33a and b) had similar class one (1) hydrographs.

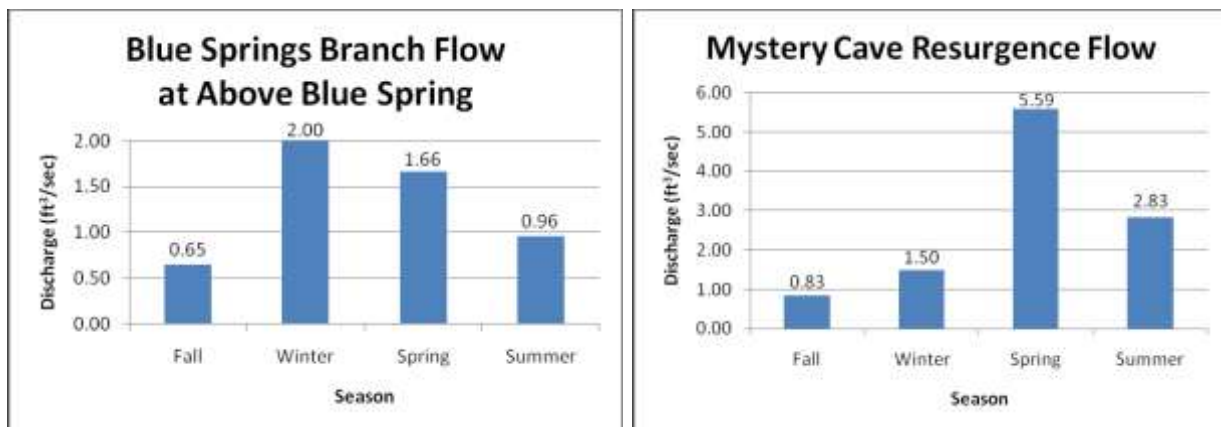


Figure 4.32. A. Quarterly baseflow discharge measurements for Blue Spring Branch above Blue Spring. B. Quarterly baseflow discharge measurements for Mystery Cave Resurgence.

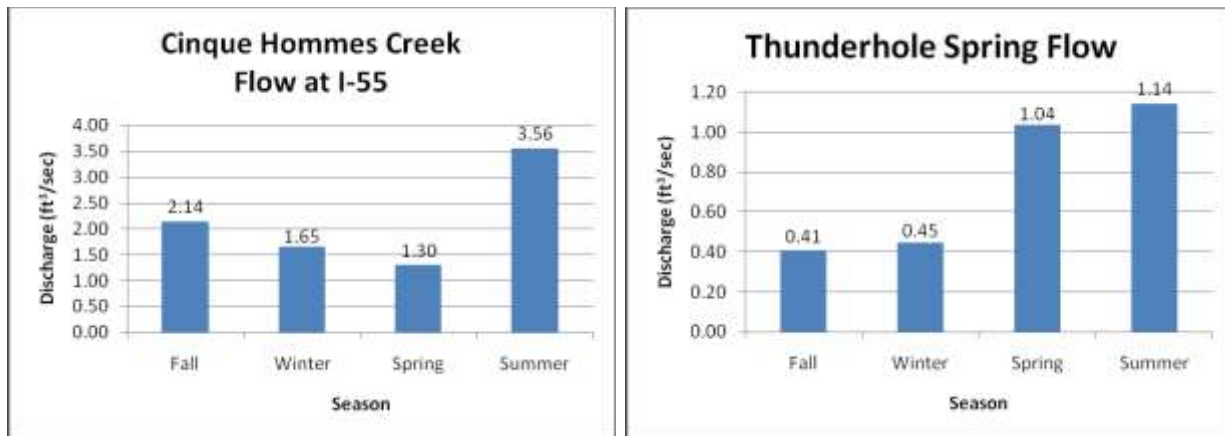


Figure 4.33. A. Quarterly baseflow discharge measurements for Tyler Branch at I-55. B. Quarterly baseflow discharge measurements for Thunderhole Resurgence.

4.2.3 Biological Data

Biological data sets for the project area are limited. The possibility of assessing changes in resident aquatic biota or assessing conditions of a stream's/watershed's health based on these data sets would be inadvisable and possibly misleading. In addition, the time lapses that have occurred since these areas were last sampled would not allow for accurate comparisons to the present conditions. Future efforts to bio-inventory surface and subsurface streams will need to be conducted throughout PCK in a routine manner in order to make inferences on current status of the biota present.

4.2.3.1 Benthic Macroinvertebrates

There are at least 183 species of benthic macroinvertebrates within the project area as illustrated in Table 4.31 (Pobst, personal communication 2012, Elliot 2005, Sutton 2009, House 2009, Taylor, personal communication 2009, MDNR 2010, MO Stream Team 2012). Several macroinvertebrates were incidental occurrences within cave systems from rainwater wash-ins. A number of benthic macroinvertebrates were found only in the larval stage of their life cycle and never in the adult stage.

Table 4.31. Species list of benthic macroinvertebrates in surface and sub-surface.

Sub-surface Surveys		Surface Surveys	
Species Type	Number of species	Species Type	Number of species
Planarian	9	Ephemeroptera	Unidentified
Earthworm	7	Plecoptera	Unidentified
Snail	23	Trichoptera	Unidentified
Amphipod	7	Groups of Odonata	2
Isopod	11	Groups of Megaloptera	3
Ostracod	1	Groups of Diptera	4

Mite	6	Groups of Coleoptera	3
Spider	10	Groups of Snails	3
Millepede	9	Amphipod	Unidentified
Springtail	25	Isopod	Unidentified
Dipluran	4	Aquatic Worms	Unidentified
Beetle	26	Leeches	Unidentified
Midge	2	Mussel	20
Mosquito	2	Crayfish	2
Fly	12		
Gnat	3		
Moth	1		
Cricket	3		
Crayfish	5		
Mussel	1		

4.2.3.2 Fish

Of the 105 species of fish found within Perry County, 61 species are present in Apple Creek, 22 in Blue Springs Branch, 11 in Cinque Hommes Creek, and six in Brazeau Creek (MDC Database 2011). The Grotto Sculpin has been collected in the Moore Cave System (Berome and Tom Moore Caves), Crevice Cave System (Crevice and Mertz Caves), Mystery Cave System, Running Bull Cave System (Running Bull Cave, Maple Leaf Cave and Thunderhole Resurgence), and Rimstone River Cave System (Rimstone Cave and Hot Caverns). Five surface species of fishes have been documented in caves within the project area (MDC 2005, Sutton 2009, MDC 2010).

4.2.3.3 Aquatic Nuisance Species

Aquatic nuisance species (ANS) found in the project area include: Eurasian watermilfoil, dotted duckweed, brittle naiad, Zebra Mussels, Common Carp, Grass Carp, Bighead Carp, and Silver Carp (USGS 2011, MDC-ANS 2007). Taylor (personal communication 2009) identified *Corbicula fluminea* (Asian clam) a status survey of the mussels in Apple Creek. The presence of several tributaries of the Mississippi River within the Perry County Karst project area suggests that more ANS may be found within the area, but have not yet been documented.

GOALS AND SOLUTIONS

Section 5. GOALS, OBJECTIVES, AND MANAGEMENT STRATEGIES

The Perry County Community Economic and Environment Committee comprised of the PCFB, PCHD, Perry County Commission, Regional Planning, City of Perryville, PCSWCD, Perry County Economic Development Authority, Perryville Development Corporation, and rural landowners in conjunction with MDC, USFWS, and MoDNR determined the extent of natural resources and critical areas within PCK watershed. This determination led to the development of BMPs and the community's efforts to address those natural areas and critical habitats for the Grotto Sculpin. The PCCEEC wrote a vision statement with three primary goals for the Watershed Management Plan. The vision statement is:

Protecting our fish, by protecting our water.

The three primary goals are:

To improve and protect the water resources of Perry County Karst.

It is critical to implement BMPs and improve land stewardship to reduce pollutants entering our Perry County water resources.

With interagency support, provide guidance for karst watershed management and education; while, promoting environmentally sound practices.

It is with continued educational efforts, interagency support, community outreach, and civic engagement that we will be able to initiate and implement improved land stewardship to promote good water quality and a sustainable karst environment.

To promote the uniqueness and biodiversity of Perry County Karst watershed and its endemic Grotto Sculpin.

Perry County has the most caves in the state of Missouri and is home to the only known locations of Grotto Sculpin.

GOAL 5.1: Improve water quality throughout the Perry County Karst watershed.

Rationale: The biological monitoring that was conducted during the 319 grant demonstrated NPS pollution in the surface and subsurface streams within the PCK watershed. In addition, *E. coli* was elevated in many instances throughout the area. Herbicides were also identified as being above acceptable levels based on EPA standards. Many sinkholes and vertical drainpipes are lacking a sufficient vegetative buffer and are major pathways into the karst system resulting in the potential for increased erosion and surface born pollutants to enter into the subsurface streams. By implementing vegetative buffers or other BMPs in these areas, the potential for increased erosion will be minimized in these systems improving soil stability and reducing sediment transport. In addition, by controlling sediment transport and implementing BMPs, a

reduction in pollutants that are bound to the soils such as *E. coli*, nutrients and herbicides will likely be achieved.

Objective 5.1.1: Monitor water quality by continuous data logging and monthly grab samples to identify trends within the designated range of Grotto Sculpin. All data should be compiled within a central database for summaries and updates to the community.

Strategy 5.1.1.1: Using data sondes collect water physical readings in a continuous manner to collect water temperature, specific conductivity, dissolved oxygen, pH, total dissolved solids, and water turbidity as previously done during the Section 319 grant.

Strategy 5.1.1.2: Collect monthly grab samples to analyze for NO_3^- -N, NO_2^- -N, NH_3 -N, Cl^- , PO_4^{3-} -P, P_{total} , *E. coli*, total coliforms, TDS, and TSS as previously done during the Section 319 grant. In addition, monthly grab herbicide samples will be analyzed for acetochlor, alachlor, atrazine, deethylatrazine, deisopropylatrazine, metolachlor, metribuzin, and simazine or any other commonly used herbicide.

Strategy 5.1.1.3: Deploy POCIS and SPMDs to collect and analyze for pesticides, plasticizers, personal care products, pharmaceuticals, PAHs, wood preservatives, surfactants, and fragrances as previously done during the Section 319 grant and Fox *et al.* 2010 study.

Objective 5.1.2: Reduce sediment and nutrient transport by increasing vegetative buffers, riparian corridors or other acceptable BMPs near streams, sinkholes, springs, and vertical drainpipes in PCK. Although Missouri does not have specific numeric criteria for sediment and nutrients, pollutant loading targets and reduction goals will be established using the load duration curve approach. The Region 7 RTAG values will be used to derive nutrient loading targets, while TSS targets derived from local reference data will serve as a surrogate target for sediment.

Strategy 5.1.2.1: Assess and prioritize stream riparian corridors and vegetative buffers for sinkholes, springs, and vertical drainpipes.

Strategy 5.1.2.2: Utilizing national, state, and local partnerships begin to address high priority areas by working with stakeholders implementing cost-share initiatives and BMPs* to improve soil stability and reduce sediment transport.

*BMPs will include but are not limited to native warm season grass buffers, no till, conservation tillage, strip cropping, contour farming, terraces, ponds, water and sediment control basins, grade stabilization structures, stream bank stabilization, grassed waterway, cover crops, filter strips, structural waste systems, diversions, dead bird composting (poultry farms), management grazing, livestock exclusion, pasture over seeding, alternative watering, animal confinement systems, tree plantings, and timber stand improvements.

Strategy 5.1.2.3: Manage public lands as good examples of proper karst management which includes sufficient vegetative buffers around sinkholes, springs, and vertical drainpipes in addition to appropriate stream riparian corridors. Where possible vertical drainpipes should be replaced and restored with natural cave openings.

Strategy 5.1.2.4: Identify and compile a list of alternative BMPs* to be used in urban areas near groundwater inputs (e.g., sinkholes, streams, springs, vertical drainpipes, cave openings, etc.) for proper filtration and erosion control.

*BMPs could include but are not limited to infiltration systems, perimeter sand filters, infiltration trenches, baffle boxes.

Strategy 5.1.2.5: Implement necessary buffer widths in accordance with USFWS, MDC, NRCS, and PCSWCD specifications needed in relation to vegetation type (i.e, warm and cool season grasses, shrubs, and trees) and slope needed to effectively filter sediments, nutrients, and pollutants from entering sinkholes and vertical drainpipes.

Strategy 5.1.2.6: Implement city ordinances to be developed if not already in place to protect groundwater inputs while limiting sediment transport in areas of development and construction. In addition adhere to construction and development guidelines for sediment erosion control measures (i.e., silt fences).

Strategy 5.1.2.7: Remove and/or repair malfunctioning vertical drainpipes.

Load duration curves for TSS and nutrients (total nitrogen and total phosphorus) have been developed by MoDNR for the five impaired streams in Perry County and provide an attainable goal of reducing pollutant loading. Although this nonpoint source management plan focuses primarily on the PCK region, the load duration curves for these streams were developed using topographic surface drainages, available stream flow gage data, and general assumptions of overland runoff. Missouri does not have specific numeric criteria for sediment and nutrients in streams, therefore loading targets are based on the RTAG benchmark values for nutrients and a TSS target of 6.5 mg/L was derived using the 25th percentile of all available TSS data from these streams in Perry County.¹

A load duration curve represents the stream's loading capacity, or the maximum amount of the pollutant that the stream can assimilate and still attain water quality standards. For the following load duration curves, the loading capacity is represented by the solid red curve. Moving along the curve from high flows to low flows shows the stream's decreasing assimilative capacity in terms of the expectation that water quality targets are met. Water quality impairments occur when existing pollutant loading exceeds a water body's assimilative capacity. Reducing pollutant loading to levels at or below the calculated loading capacity will result in conditions that meet water quality standards. In addition to the load duration curves, supplemental tables are also provided to show specific loading targets under various flow conditions. Although loading changes with flow (more flow = higher load), the targeted pollutant concentrations remain constant.

¹ TSS data from Dry Fork was excluded from this analysis due to evidence of possible low dissolved oxygen issues in the stream and may not be representative of an unimpaired condition.

TSS Load Duration Curve for Cinque Hommes Creek – 1781

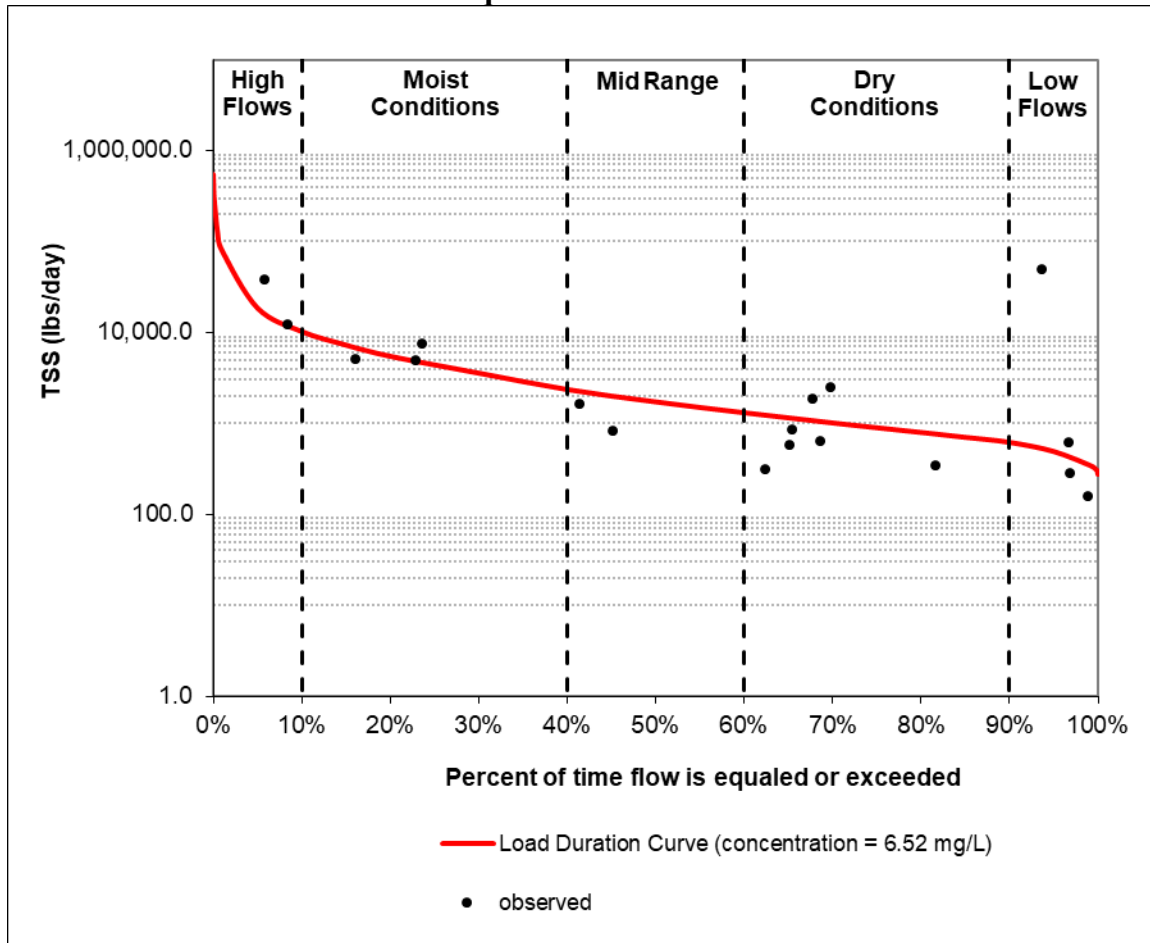


Figure 5.1.21 TSS load duration curve for Cinque Hommes Creek – 1781

Table 5.1.21 Greatest TSS load reductions needed in Cinque Hommes Creek (1781) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
94%	Low Flow	15.07	528	49,912	99%
70%	Dry Conditions	26.00	1,025	2,509	59%
41%	Mid Range	63.59	2,229	1,618	none
24%	Moist Conditions	131.17	4,599	7,660	40%
6%	High Flow	459.65	16,116	37,823	57%

* Flows given in units of cubic feet per second (cfs).

Target TSS concentration = 6.5 mg/L

Greatest needed TSS reduction = 99 percent at low flow conditions

Total Nitrogen (TN) Load Duration Curve for Cinque Hommes Creek – 1781

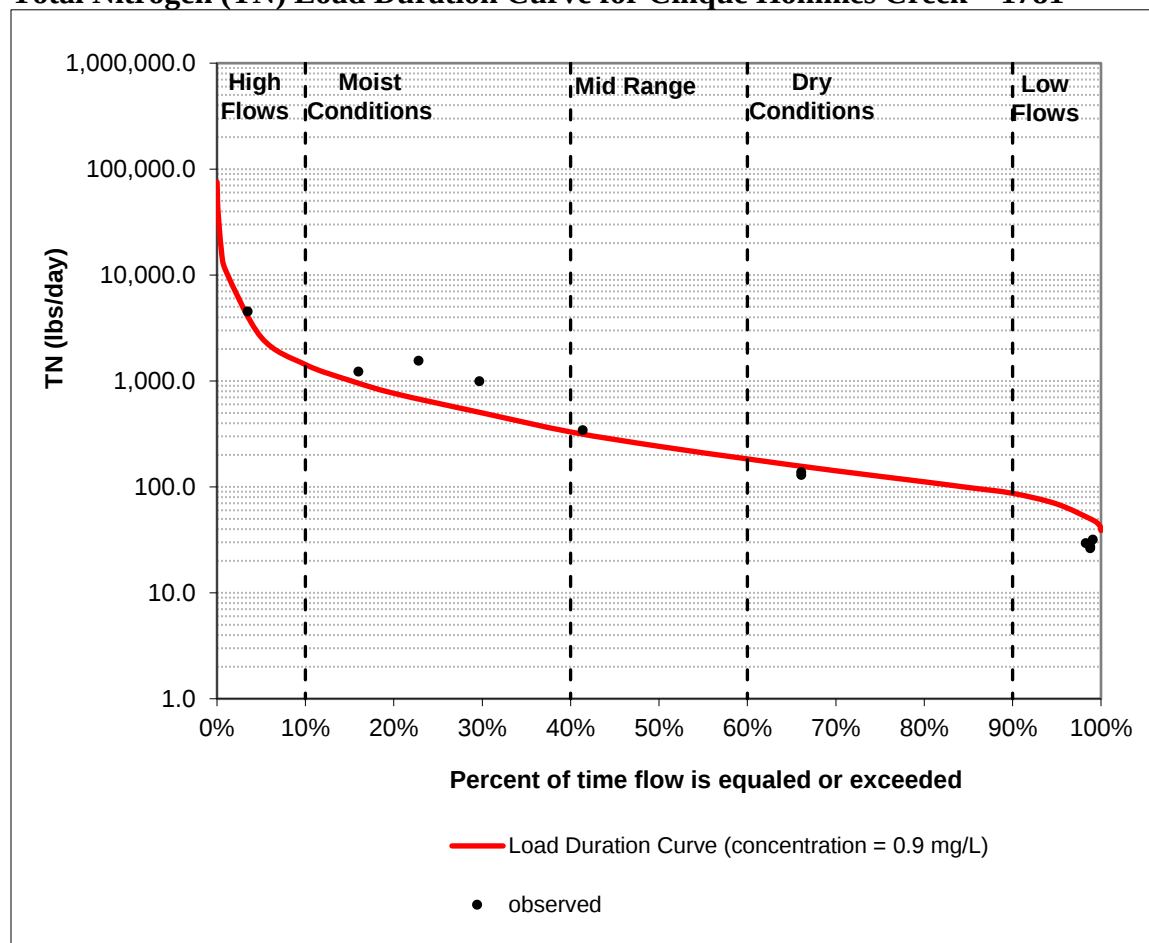


Figure 5.1.22 TN load duration curve for Cinque Hommes Creek – 1781

Table 5.1.22 Greatest TN load reductions needed in Cinque Hommes Creek (1781) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
99%	Low Flow	10.09	49	32	None
66%	Dry Conditions	26.00	158	129	None
41%	Mid Range	65.48	318	343	7%
23%	Moist Conditions	136.65	664	1,550	57%
4%	High Flow	649.54	3,153	4,519	None

* Flows given in units of cubic feet per second (cfs).

Target TN concentration = 0.9 mg/L

Greatest needed TN reduction = 57 percent at moist conditions

Total Phosphorus (TP) Load Duration Curve for Cinque Hommes Creek – 1781

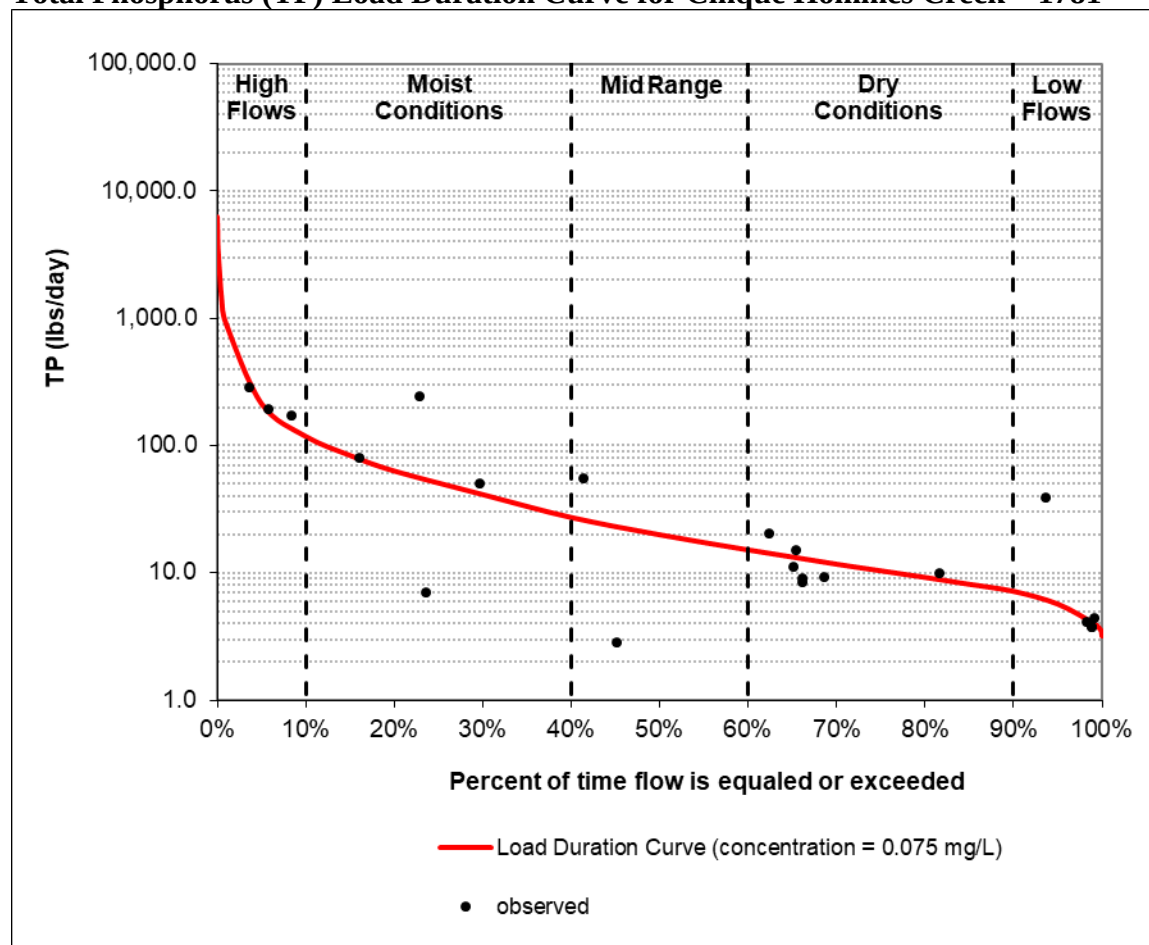


Figure 5.1.23 TP load duration curve for Cinque Hommes Creek – 1781

Table 5.1.23 Greatest TP load reductions needed in Cinque Hommes Creek (1781) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
94%	Low Flow	15.07	6	39	85%
62%	Dry Conditions	26.00	15	20	29%
41%	Mid Range	63.59	26	55	53%
23%	Moist Conditions	136.65	55	244	77%
8%	High Flow	362.30	147	171	14%

* Flows given in units of cubic feet per second (cfs).

Target TP concentration = 0.075 mg/L

Greatest needed TP reduction = 85 percent at low flows

TSS Load Duration Curve for McClanahan Creek – 1786

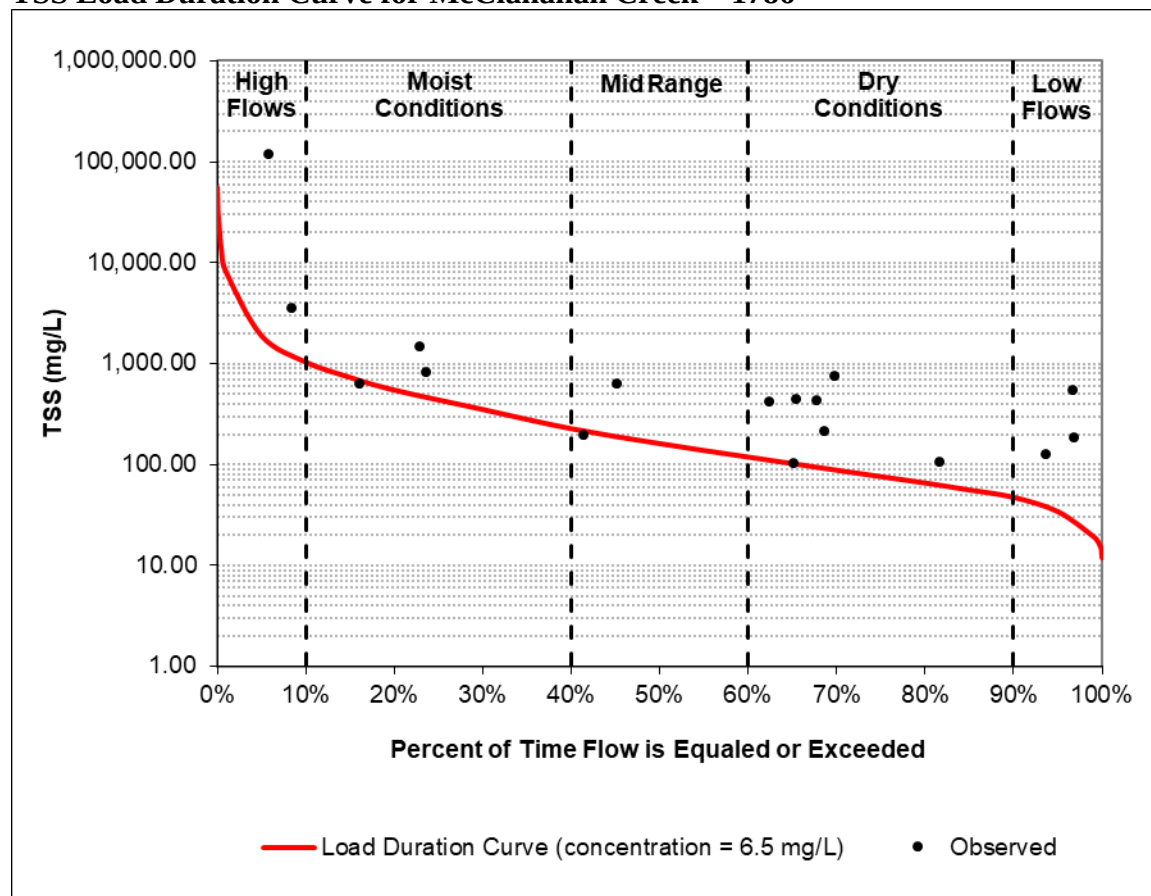


Figure 5.1.24 TSS load duration curve for McClanahan Creek - 1786

Table 5.1.24 Greatest TSS load reductions needed in McClanahan Creek (1786) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
97%	Low Flow	0.82	29	557	95%
70%	Dry Conditions	2.53	89	753	88%
45%	Mid Range	5.49	192	628	69%
23%	Moist Conditions	13.60	477	1,479	68%
6%	High Flow	46.87	1,643	118,898	99%

* Flows given in units of cubic feet per second (cfs).

Target TSS concentration = 6.5 mg/L

Greatest needed TP reduction = 99 percent at high flows

Total Nitrogen (TN) Load Duration Curve for McClanahan Creek – 1786

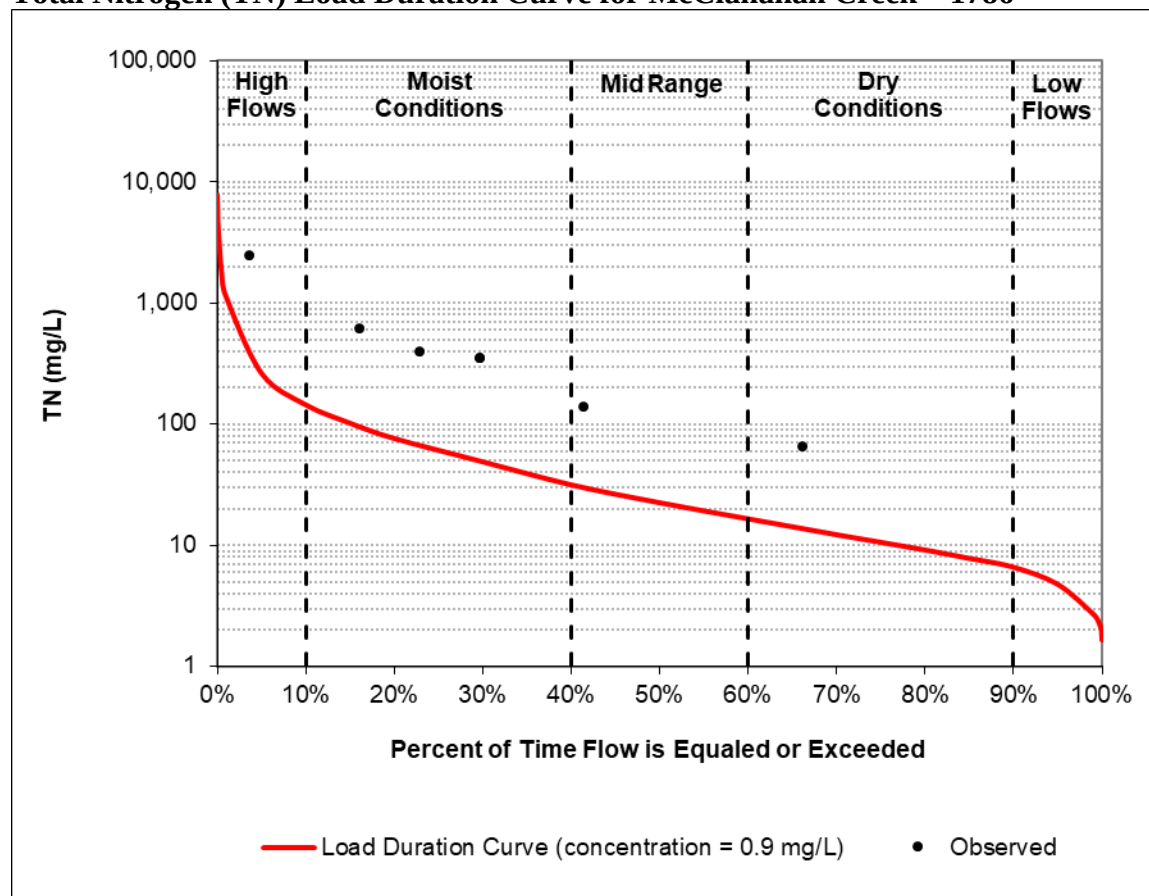


Figure 5.1.25 TN load duration curve for McClanahan Creek - 1786

Table 5.1.25 Greatest TN load reductions needed in McClanahan Creek (1786) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
95%	Low Flow	0.98	5	No data	No data
66%	Dry Conditions	2.86	14	66	79%
41%	Mid Range	6.27	30	140	78%
30%	Moist Conditions	10.11	49	353	86%
4%	High Flows	66.43	323	2,456	87%

* Flows given in units of cubic feet per second (cfs).

Target TN concentration = 0.9 mg/L

Greatest needed TN reduction = 87 percent at high flows

Total Phosphorus (TP) Load Duration Curve for McClanahan Creek – 1786

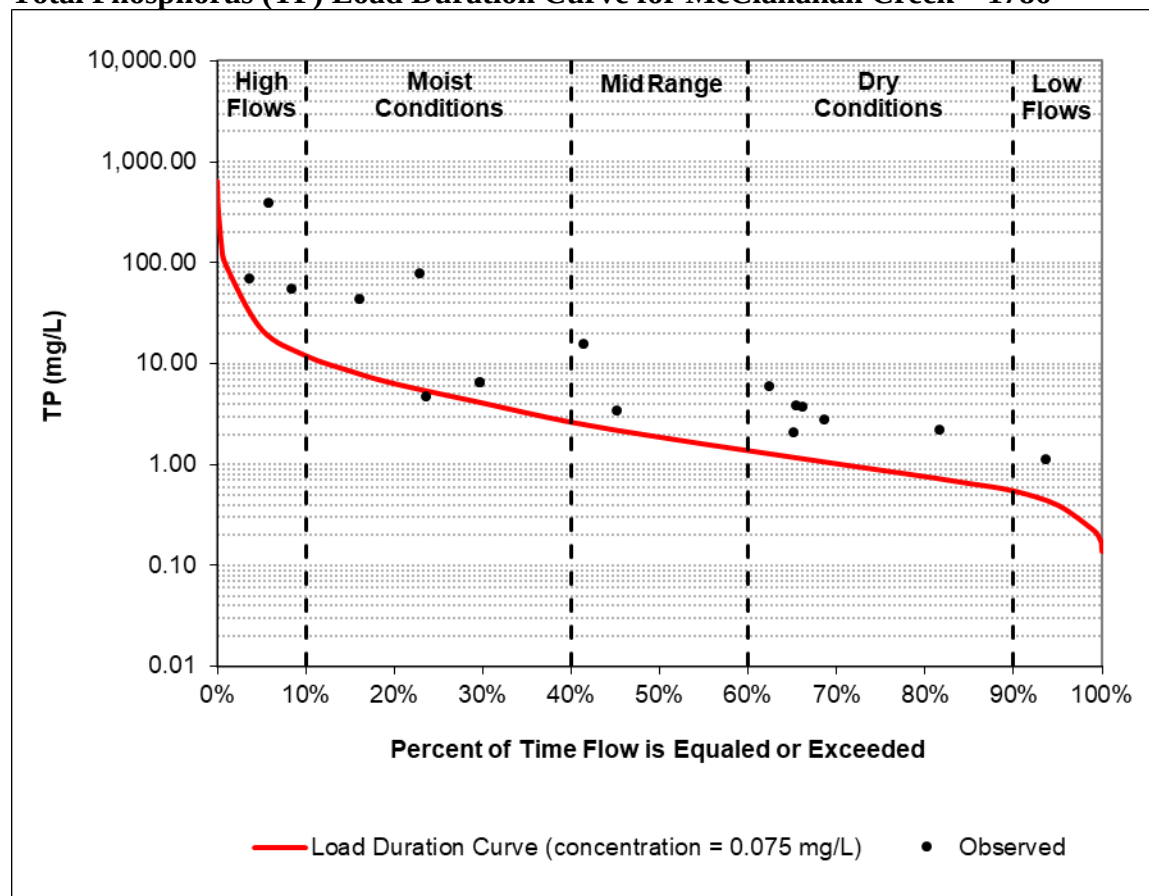


Figure 5.1.26 TP load duration curve for McClanahan Creek - 1786

Table 5.1.26 Greatest TP load reductions needed in McClanahan Creek (1786) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
94%	Low Flow	1.07	0	1	62%
62%	Dry Conditions	3.22	1	6	78%
41%	Mid Range	6.27	3	16	84%
23%	Moist Conditions	13.60	6	80	93%
6%	High Flows	46.87	19	393	95%

* Flows given in units of cubic feet per second (cfs).

Target TP concentration = 0.9 mg/L

Greatest needed TP reduction = 95 percent at high flows

TSS Load Duration Curve for Dry Fork – 1792

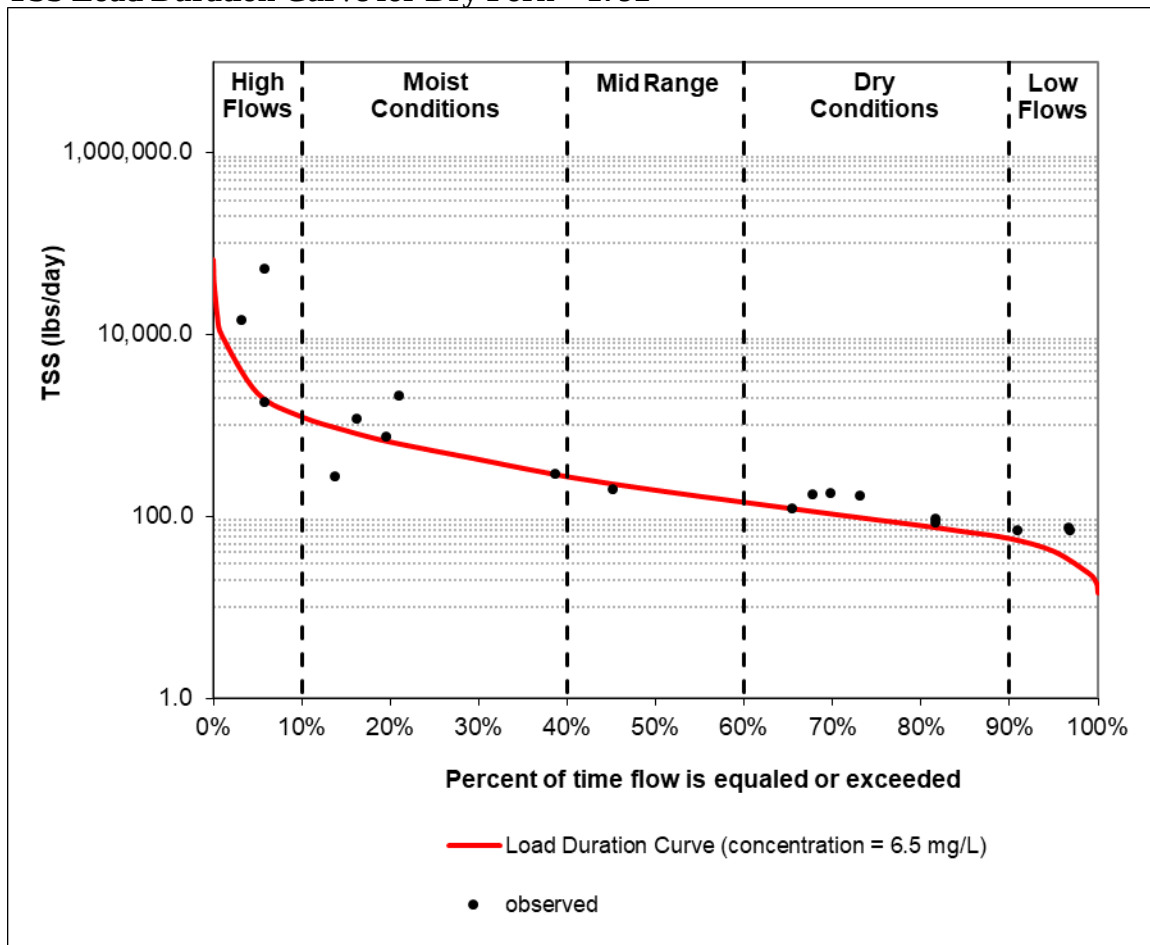


Figure 5.1.27 TSS load duration curve for Dry Fork - 1792

Table 5.1.27 Greatest TSS load reductions needed in Dry Fork (1792) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
97%	Low Flow	0.98	34	70	51%
73%	Dry Conditions	26.00	97	168	42%
50%	Mid Range	5.52	193	1,618	None
21%	Moist Conditions	17.91	628	2,161	71%
6%	High Flow	55.68	1,952	52,741	96%

* Flows given in units of cubic feet per second (cfs).

Target TSS concentration = 6.5 mg/L

Greatest needed TSS reduction = 96 percent at high flows

Total Nitrogen (TN) Load Duration Curve for Dry Fork – 1792

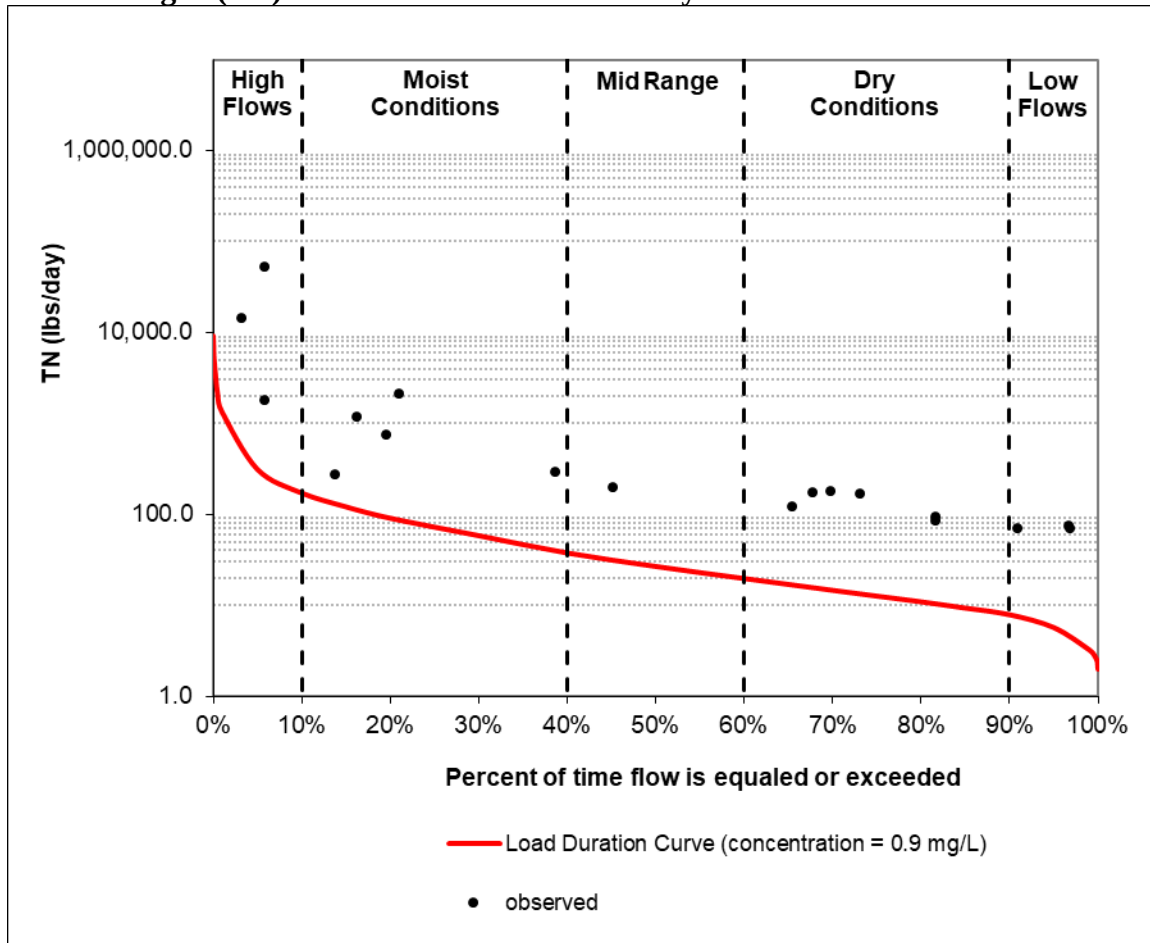


Figure 5.1.28 TN load duration curve for Dry Fork - 1792

Table 5.1.28 Greatest TN load reductions needed in Dry Fork (1792) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
95%	Low Flow	1.17	6	No data	No data
66%	Dry Conditions	26.00	17	37	55%
41%	Mid Range	7.44	36	89	59%
30%	Moist Conditions	12.01	58	239	76%
4%	High Flow	78.91	383	1,517	75%

* Flows given in units of cubic feet per second (cfs).

Target TN concentration = 0.9 mg/L

Greatest needed TN reduction = 76 percent at moist conditions

Total Phosphorus (TP) Load Duration Curve for Dry Fork – 1792

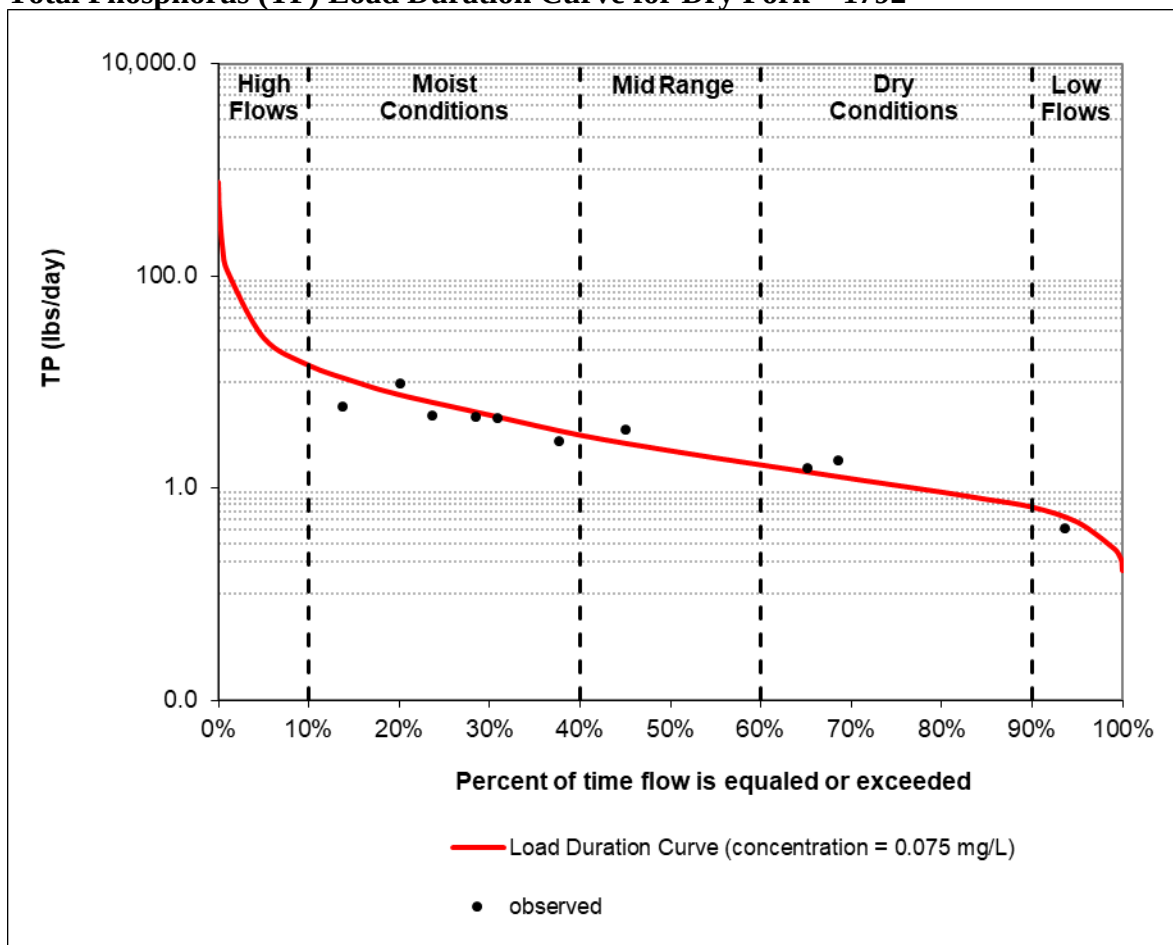


Figure 5.1.29 TP load duration curve for Dry Fork - 1792

Table 5.1.29 Greatest TP load reductions needed in Dry Fork (1792) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
94%	Low Flow	1.17	0.47	0.42	None
69%	Dry Conditions	26.00	1.38	1.84	25%
45%	Mid Range	7.44	3.01	3.57	16%
20%	Moist Conditions	12.01	4.86	9.68	50%
4%	High Flow	78.91	31.92	No data	No data

* Flows given in units of cubic feet per second (cfs).

Target TP concentration = 0.075 mg/L

Greatest needed TP reduction = 50 percent at moist conditions

Total Suspended Solids (TSS) Load Duration Curve for Brazeau Creek (1796)

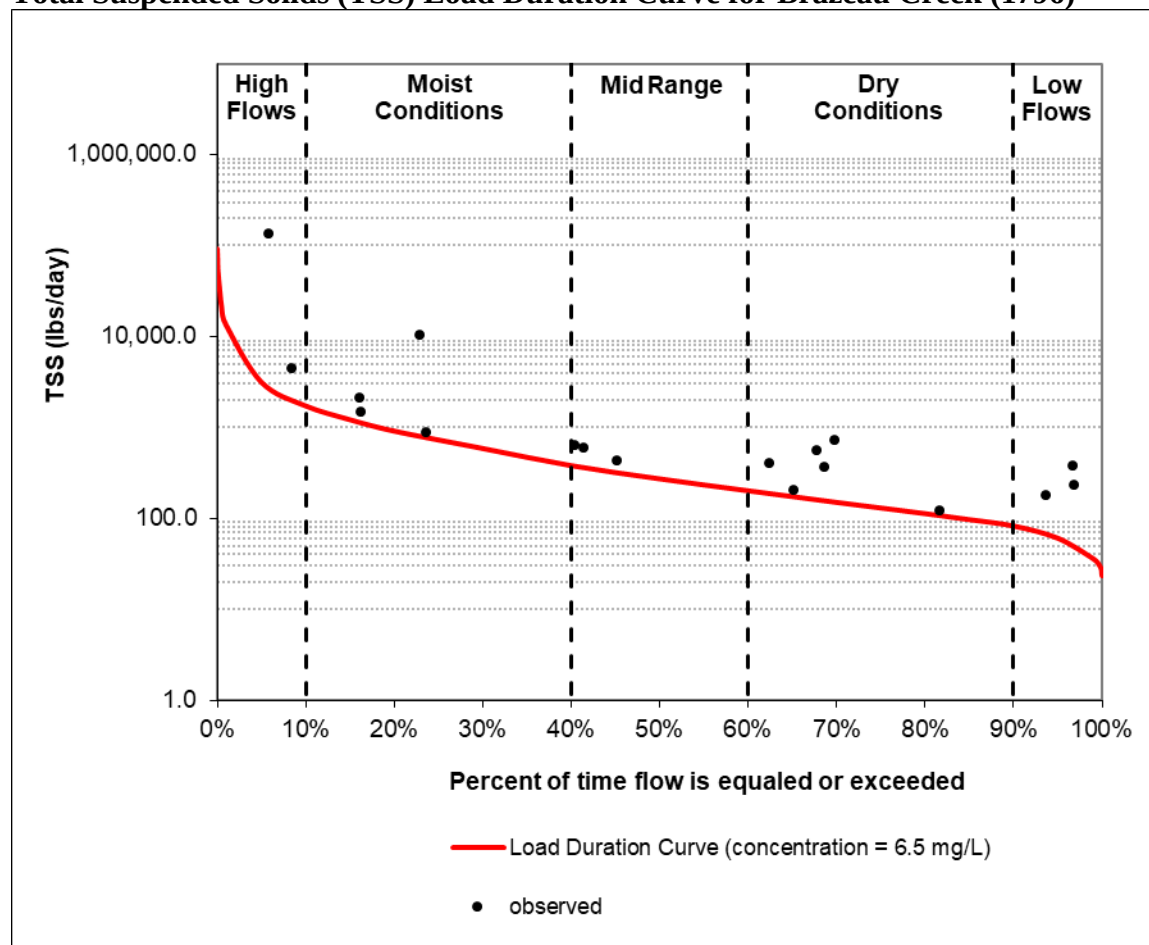


Figure 5.1.210 TSS load duration curve for Brazeau Creek (1796)

Table 5.1.210 Greatest TSS load reductions needed in Brazeau Creek (1796) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
97%	Low Flow	1.46	51	378	86%
70%	Dry Conditions	26.00	151	730	79%
41%	Mid Range	10.49	368	608	39%
23%	Moist Conditions	22.65	794	10,545	92%
6%	High Flow	77.84	2,729	135,195	98%

* Flows given in units of cubic feet per second (cfs).

Target TSS concentration = 6.5 mg/L

Greatest needed TSS reduction = 98 percent at high flows

Total Nitrogen (TN) Load Duration Curve for Brazeau Creek (1796)

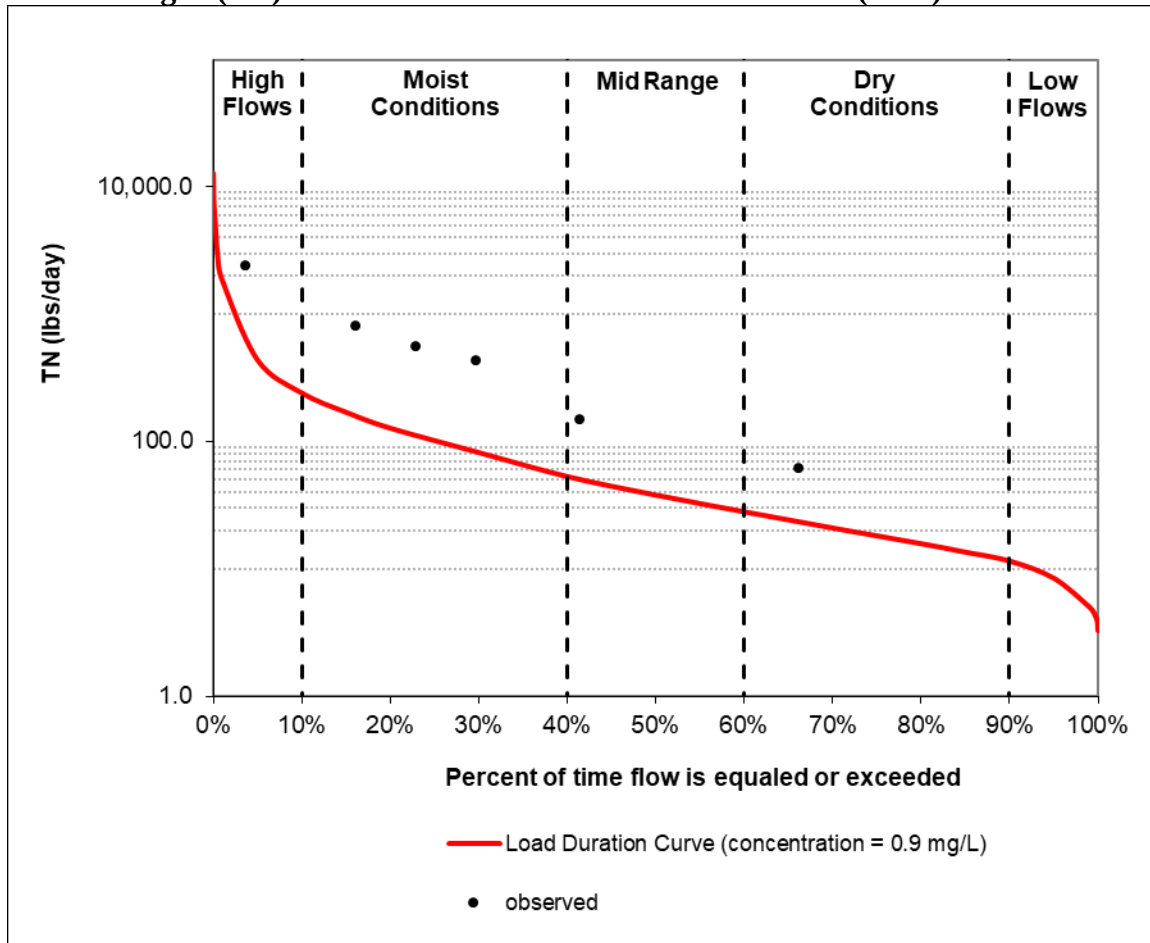


Figure 5.1.211 TN load duration curve for Brazeau Creek (1796)

Table 5.1.211 Greatest TN load reductions needed in Brazeau Creek (1796) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
95%	Low Flow	1.73	8	No Data	No Data
66%	Dry Conditions	26.00	24	61	61%
41%	Mid Range	10.49	51	149	66%
16%	Moist Conditions	32.71	159	806	80%
4%	High Flow	110.28	535	2,412	78%

* Flows given in units of cubic feet per second (cfs).

Target TN concentration = 0.9 mg/L

Greatest needed TN reduction = 86 percent at moist conditions

Total Phosphorus (TP) Load Duration Curve for Brazeau Creek (1796)

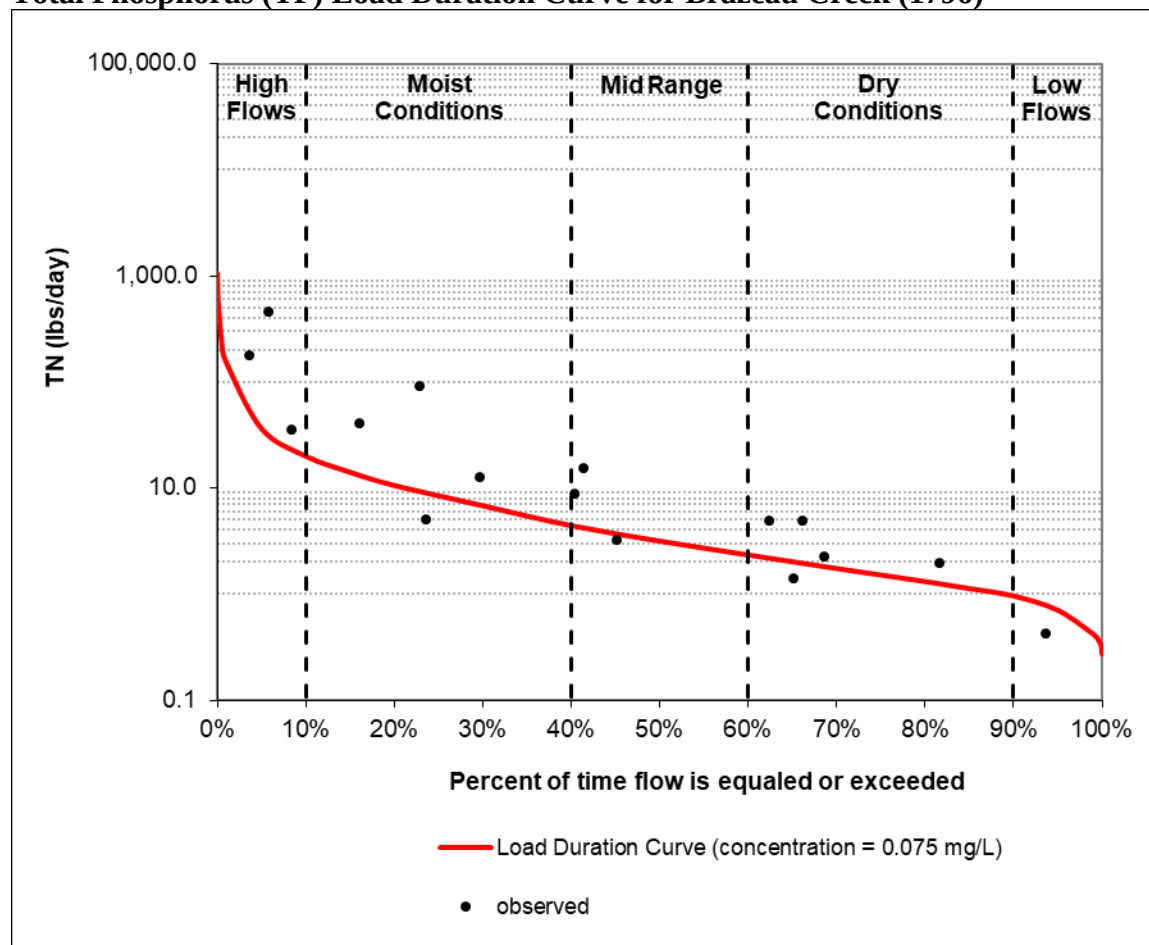


Figure 5.1.212 TP load duration curve for Brazeau Creek (1796)

Table 5.1.212 Greatest TP load reductions needed in Brazeau Creek (1796) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
94%	Low Flow	1.88	0.76	0.43	0%
66%	Dry Conditions	26.00	1.96	4.86	60%
41%	Mid Range	10.49	4.25	15.36	72%
23%	Moist Conditions	22.65	9.16	92.72	90%
6%	High Flow	77.84	31.49	455.03	93%

* Flows given in units of cubic feet per second (cfs).

Target TP concentration = 0.075 mg/L

Greatest needed TP reduction = 93 percent at high flows

Total Suspended Solids (TSS) Load Duration Curve for Omete Creek - 1794

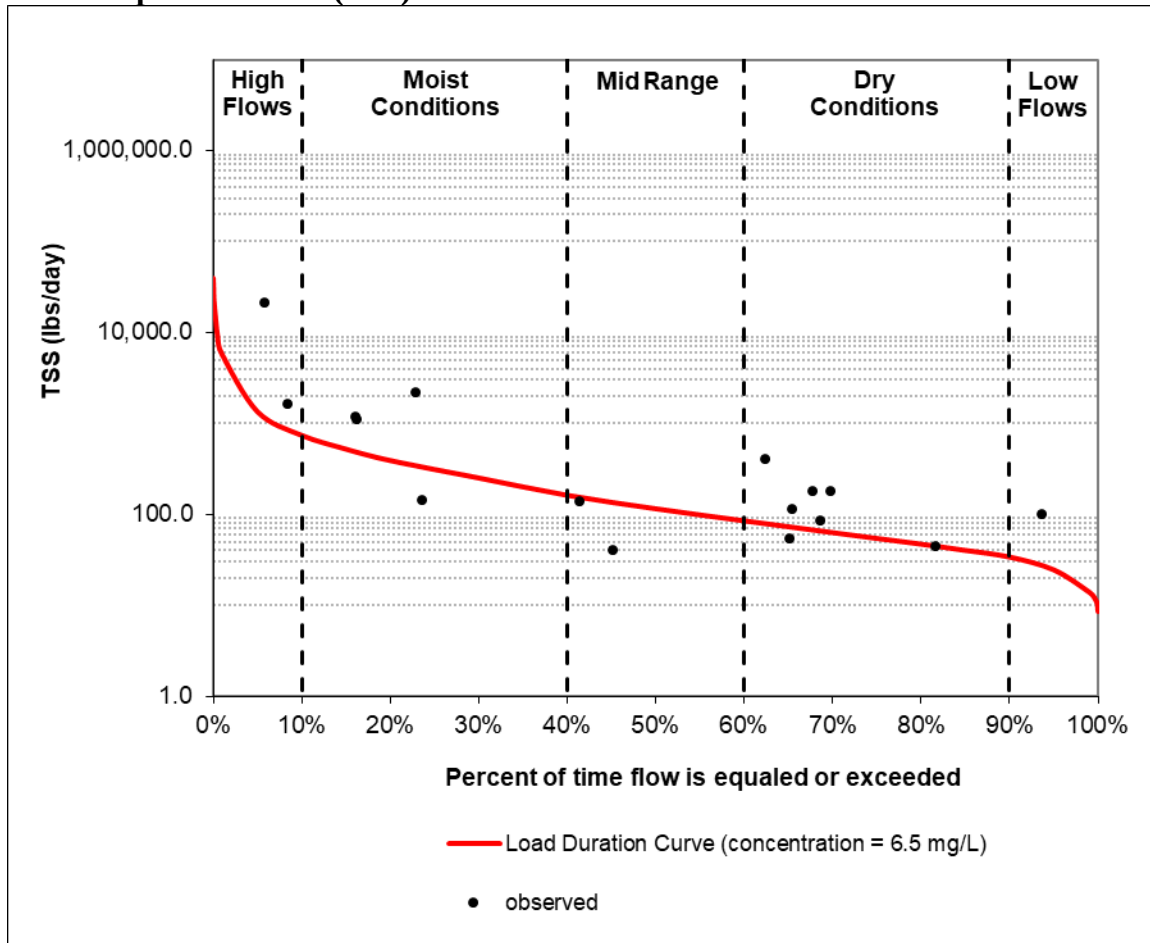


Figure 5.1.213 TSS load duration curve for Omete Creek (1794)

Table 5.1.213 Greatest TSS load reductions needed in Omete Creek (1794) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
94%	Low Flow	0.75	26	102	74%
62%	Dry Conditions	26.00	79	408	81%
41%	Mid Range	4.40	154	140	0%
23%	Moist Conditions	9.54	335	2,179	85%
6%	High Flow	32.89	1,153	21,108	95%

* Flows given in units of cubic feet per second (cfs).

Target TSS concentration = 6.5 mg/L

Greatest needed TSS reduction = 95 percent at high flows

Total Nitrogen (TN) Load Duration Curve for Omete Creek - 1794

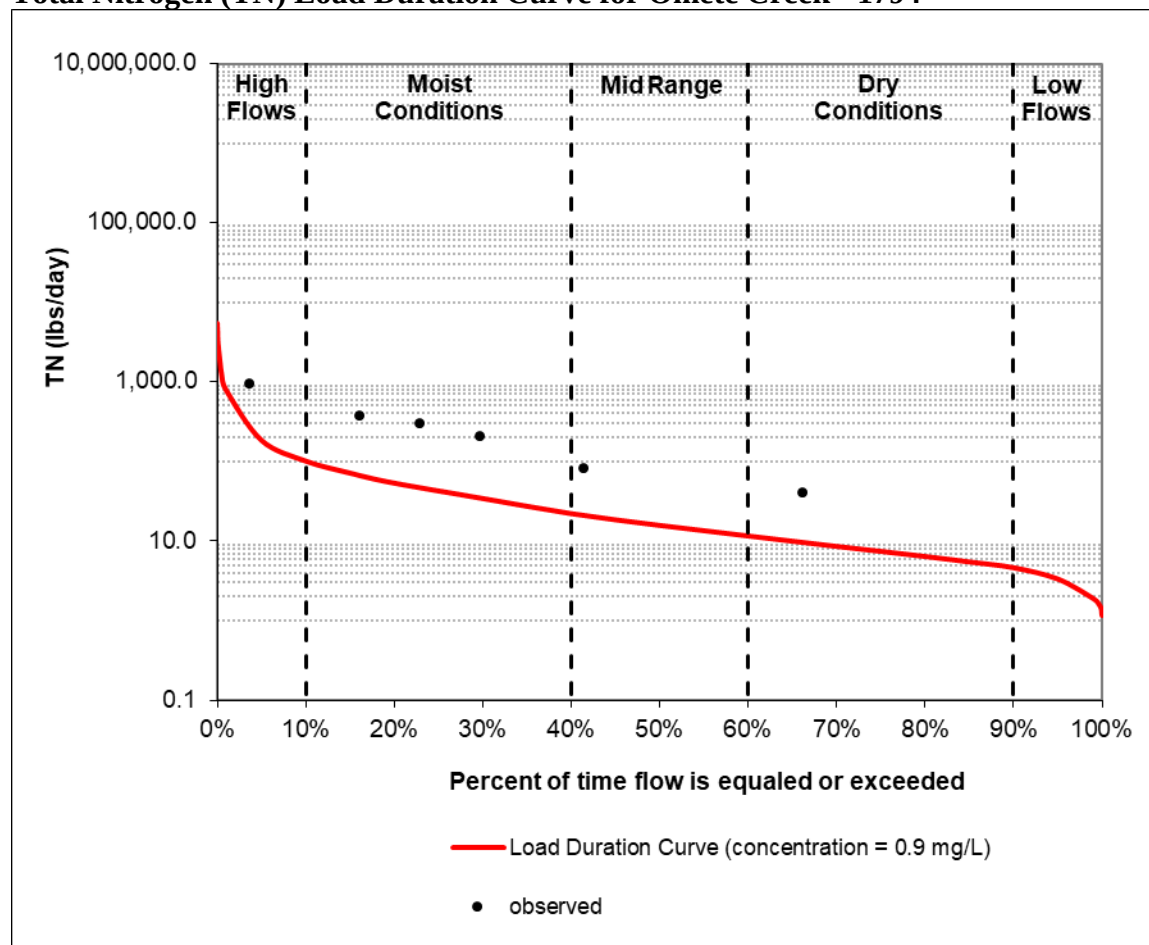


Figure 5.1.214 TN load duration curve for Omete Creek (1794)

Table 5.1.214 Greatest TN load reductions needed in Omete Creek (1794) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
95%	Low Flow	0.69	3	No data	No data
66%	Dry Conditions	26.00	10	40	76%
41%	Mid Range	4.40	21	81	74%
30%	Moist Conditions	9.54	46	208	78%
4%	High Flow	46.61	226	948	76%

* Flows given in units of cubic feet per second (cfs).

Target TN concentration = 0.9 mg/L

Greatest needed TN reduction = 78 percent at moist conditions

Total Phosphorus (TP) Load Duration Curve for Omete Creek - 1794

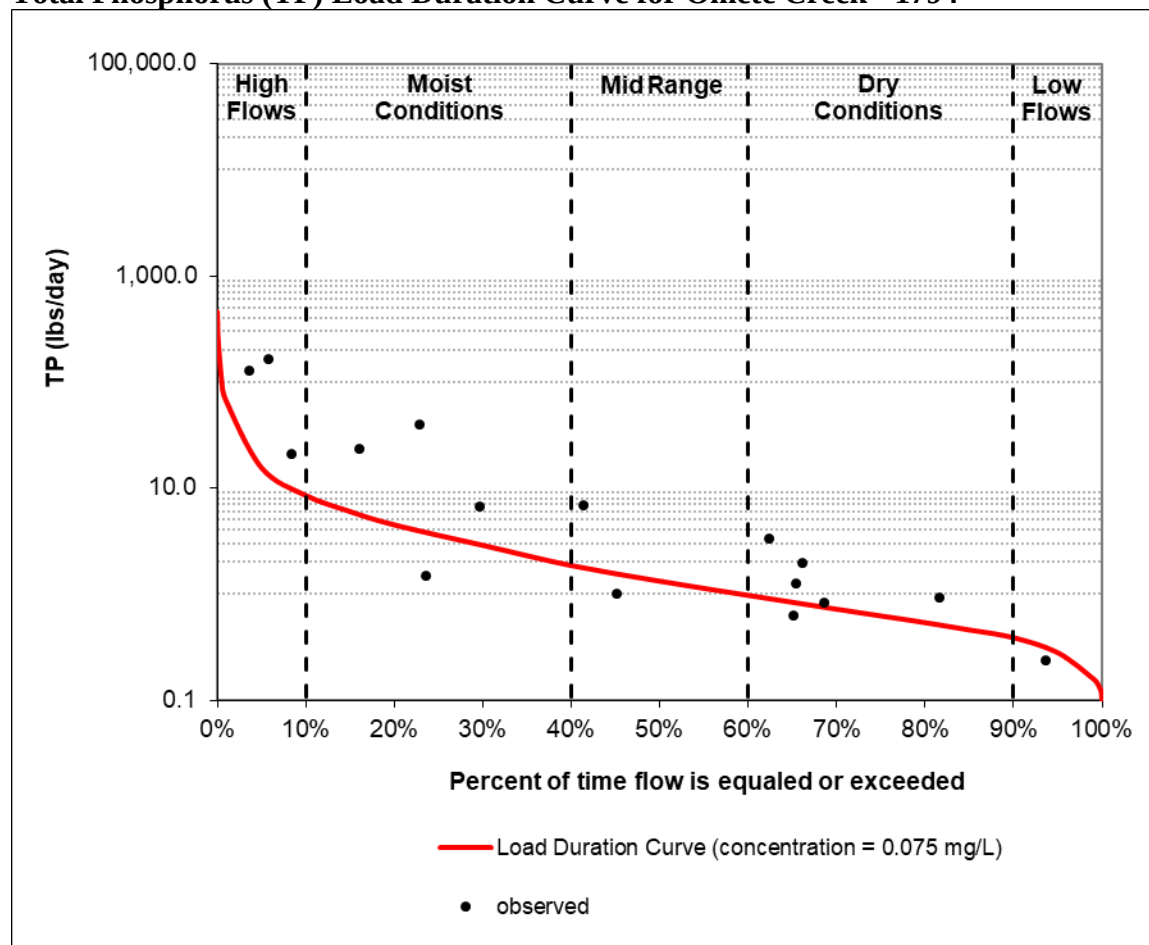


Figure 5.1.215 TP load duration curve for Omete Creek (1794)

Table 5.1.215 Greatest TP load reductions needed in Omete Creek (1794) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Pollutant Reduction (%)
94%	Low Flow	0.75	0.30	0.24	0%
62%	Dry Conditions	26.00	0.91	3.38	73%
41%	Mid Range	4.40	1.78	6.86	74%
23%	Moist Conditions	9.54	3.86	39.23	90%
6%	High Flow	46.61	18.86	162.89	88%

* Flows given in units of cubic feet per second (cfs).

Target TP concentration = 0.075 mg/L

Greatest needed TP reduction = 90 percent at moist conditions

Objective 5.1.3. Reduce *E. coli* levels with the intent that levels are in compliance with the Missouri Water Quality Standards. For *E. coli* impaired waters, loading targets and pollutant reduction goals have been established using the load duration curve approach.

Strategy 5.1.3.1: Assess the extent and placement of septic systems within the major recharge areas that could be impacting PCK.

Strategy 5.1.3.2: Establish a monitoring and examination protocol for septic systems and underground storage tanks.

Strategy 5.1.3.3: Use of cost-share incentives and/or other funding sources to replace inadequate or improve malfunctioning septic systems. Septic systems that directly dump into a sinkhole and/or cave should be of highest priority.

Strategy 5.1.3.4: Develop programs to assist with septic system maintenance. These could include pump out programs, unclogging leach field lines, so that these systems meet or exceed specifications set forth by MoDNR, and PCHD.

Strategy 5.1.3.5: Implement BMPs* for livestock, in an effort to reduce animal introduced *E. coli* levels found within the PCK watershed.

*BMPs will include but are not limited to structural waste systems, management grazing, livestock exclusion, pasture over seeding, alternative watering, animal confinement systems.

Load duration curves for *E. coli* have been developed by MoDNR for the five impaired streams in Perry County and provide an attainable goal of reducing pollutant loading. Although this nonpoint source management plan focuses primarily on the PCK region, the load duration curves for these streams were developed using topographic surface drainages (Figure 5.1), available stream flow gage data, and general assumptions of overland runoff.

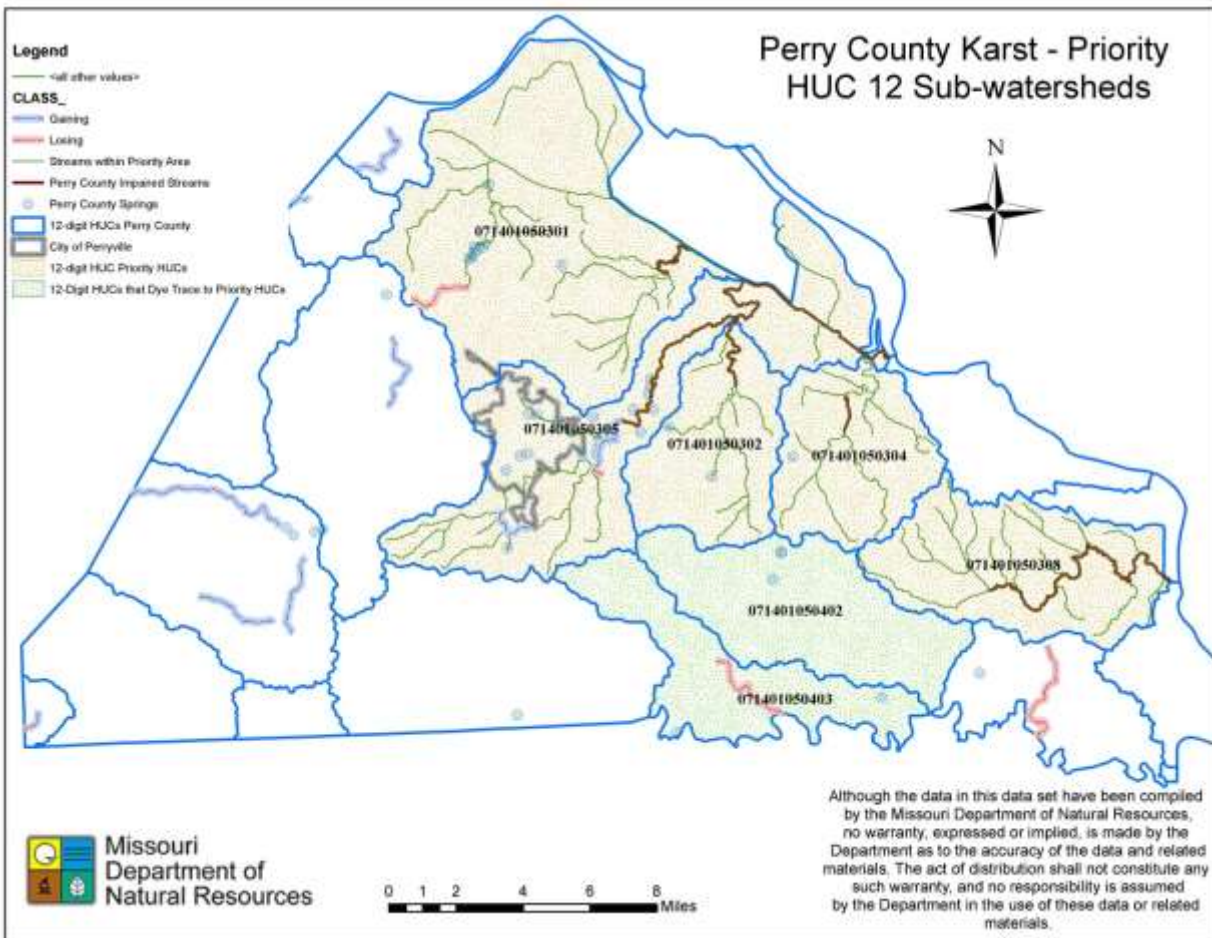


Figure 5.1.31. Map created by MoDNR depicting the HUC 12-watersheds containing 303(d) listed impaired waters.

A load duration curve represents the stream's loading capacity, or the maximum amount of the pollutant that the stream can assimilate and still attain water quality standards. For the following load duration curves, the loading capacity is represented by the solid red curve. Moving along the curve from high flows to low flows shows the stream's decreasing assimilative capacity in terms of the expectation that water quality standards are met at the target *E. coli* concentration of 206 counts/100 mL of water. This target concentration was chosen for calculation of the load duration curves, because it is consistent with the *E. coli* criterion for the protection of the whole body contact recreation category B use designated in Missouri's water quality standards to the impaired streams. Water quality impairments occur because the existing *E. coli* loading exceeds the assimilative capacity of these water bodies. The *E. coli* loading to the impaired water bodies must be reduced to levels at or below the loading capacity if it is to meet water quality standards. In addition to the load duration curves, supplemental tables are also provided to show specific loading targets under various flow conditions. Although loading changes with flow (more flow = higher load), the target concentration of 206/100 mL remains constant.

Load Duration Curve for Cinque Hommes Creek - 1781

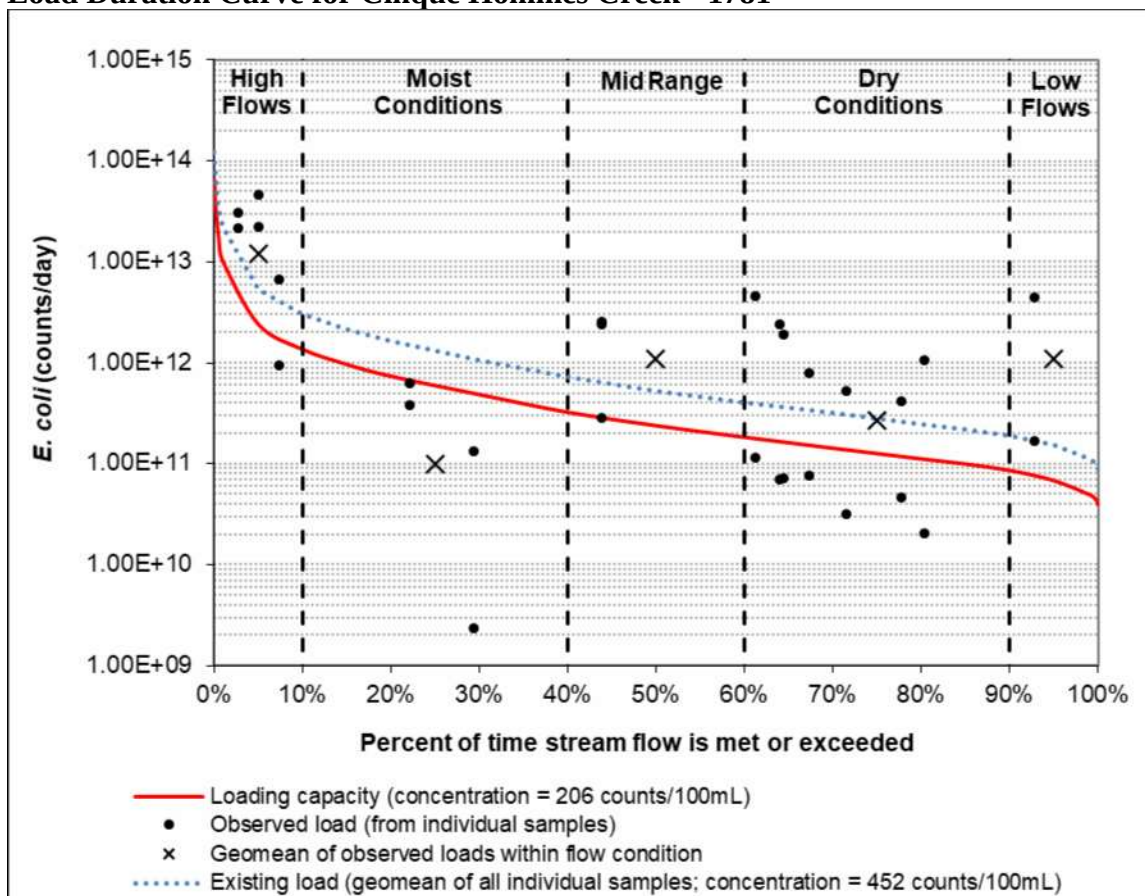


Figure 5.1.32 Load duration curve for Cinque Hommes Creek, water body ID 1781

Table 5.1.31 Loads in Cinque Hommes Creek (1781) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Loading Capacity (counts/day)	Existing Load (counts/day)
95	Low Flow	13.72	6.29E+10	1.52E+11
75	Dry Conditions	25.43	1.28E+11	2.81E+11
50	Mid Range	47.89	2.41E+11	5.29E+11
25	Moist Conditions	119.82	6.04E+11	1.32E+12
5%	High Flow	479.99	2.42E+12	5.30E+12

* Flows given in units of cubic feet per second (cfs).

Target *E. coli* concentration = 206 counts/100 mL

Overall needed *E. coli* reduction to attain water quality standards = 54 percent

All municipal and domestic wastewater dischargers in the Cinque Hommes Creek watershed disinfect their effluent and there are no concentrated animal feeding operations (CAFOs) in this watershed. Other permitted facilities operating in compliance with site-specific industrial, general wastewater, or general stormwater permits are not expected to contribute bacteria loads above *de minimis* levels. For this reason, point sources are not expected to contribute to the impairment and no pollutant reductions from point sources are necessary to achieve the specified loading targets.

Load Duration Curve for McClanahan Creek - 1786

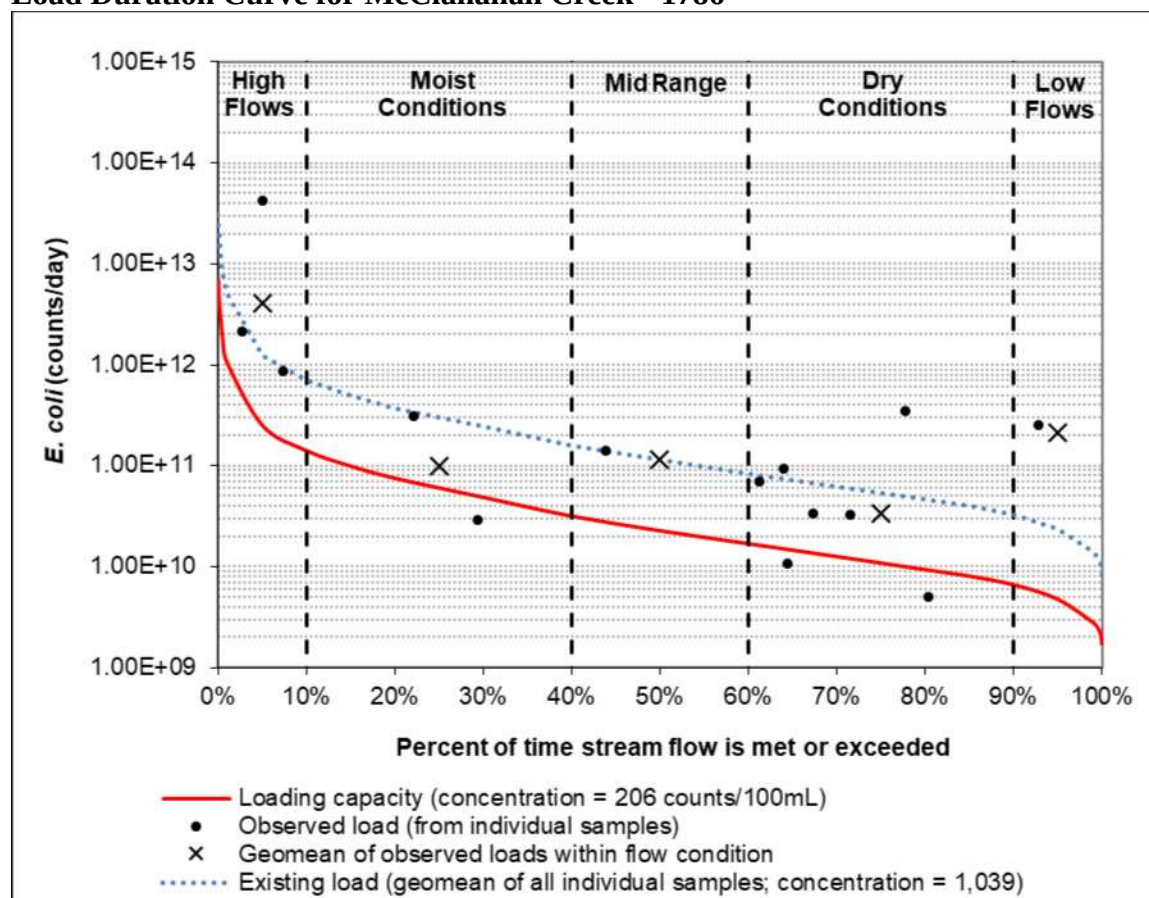


Figure 5.1.33 Load duration curve for McClanahan Creek, water body ID 1786

Table 5.1.32 Loads in McClanahan Creek (1786) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Loading Capacity (counts/day)	Existing Load (counts/day)
95	Low Flow	0.93	4.71E+09	2.38E+10
75	Dry Conditions	2.14	1.08E+10	5.44E+10
50	Mid Range	4.45	2.25E+10	1.13E+11
25	Moist Conditions	11.86	5.98E+10	3.02E+11
5%	High Flow	48.97	2.47E+11	1.24E+12

* Flows given in units of cubic feet per second (cfs).

Target *E. coli* concentration = 206 counts/100 mL

Overall needed *E. coli* reduction to attain water quality standards = 80 percent

There are no municipal or domestic dischargers or CAFOs in the McClanahan Creek watershed. The only permitted facility in the watershed is a site-specific industrial stormwater permit issued to the Perry County Landfill. This landfill is closed and capped. Therefore it is not expected to be a significant source of bacteria. For these reasons, point sources are not expected to contribute bacteria loading above *de minimis* levels and no pollutant reductions from point sources are necessary to achieve the specified loading targets.

Load Duration Curve for Dry Fork – 1792

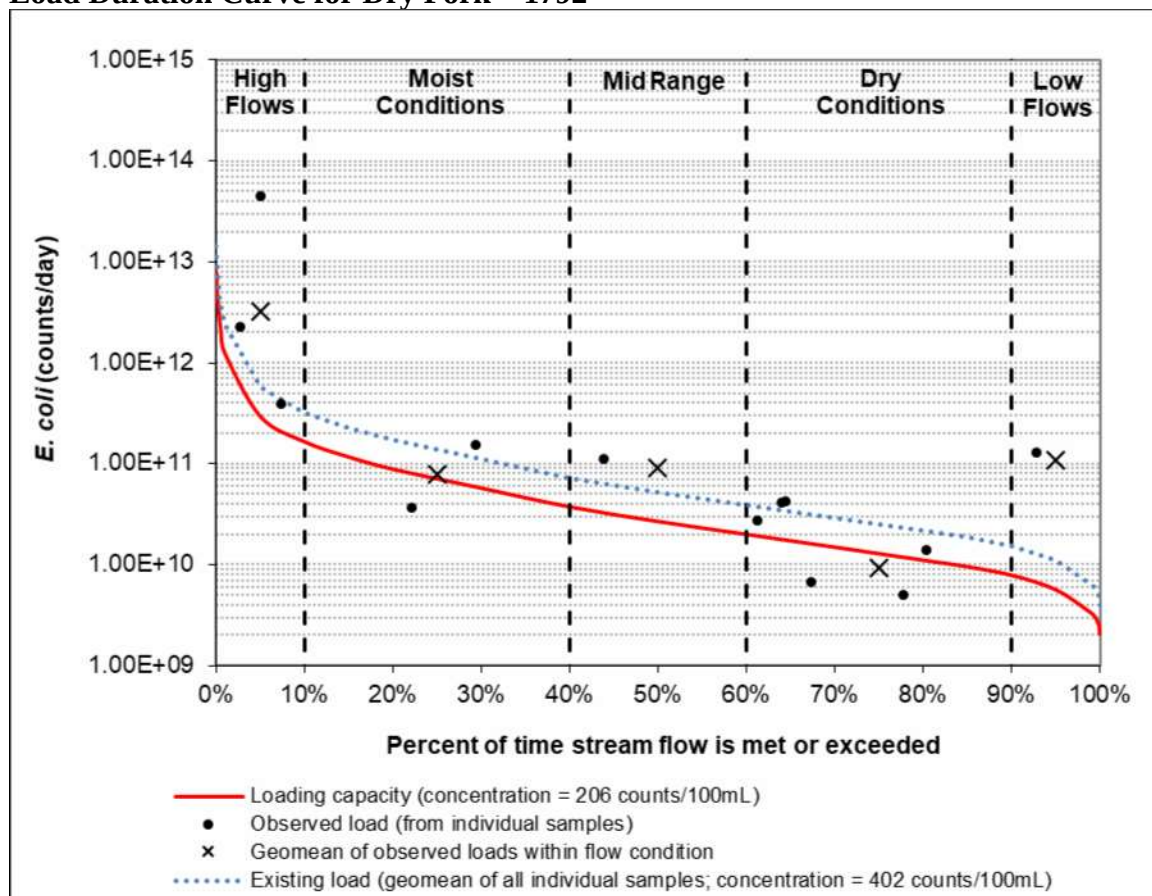


Figure 5.1.34 Load duration curve for Dry Fork, water body ID 1792

Table 5.1.33 Loads in Dry Fork (1792) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Loading Capacity (counts/day)	Existing Load (counts/day)
95	Low Flow	1.11	5.59E+09	1.09E+10
75	Dry Conditions	2.54	1.28E+10	2.50E+10
50	Mid Range	5.29	2.67E+10	5.20E+10
25	Moist Conditions	14.09	7.10E+10	1.39E+11
5%	High Flow	58.17	2.93E+11	5.72E+11

* Flows given in units of cubic feet per second (cfs).

Target *E. coli* concentration = 206 counts/100 mL

Overall needed *E. coli* reduction to attain water quality standards = 49 percent

There are no permitted point sources in the Dry Fork watershed.

Load Duration Curve for Omete Creek – 1794

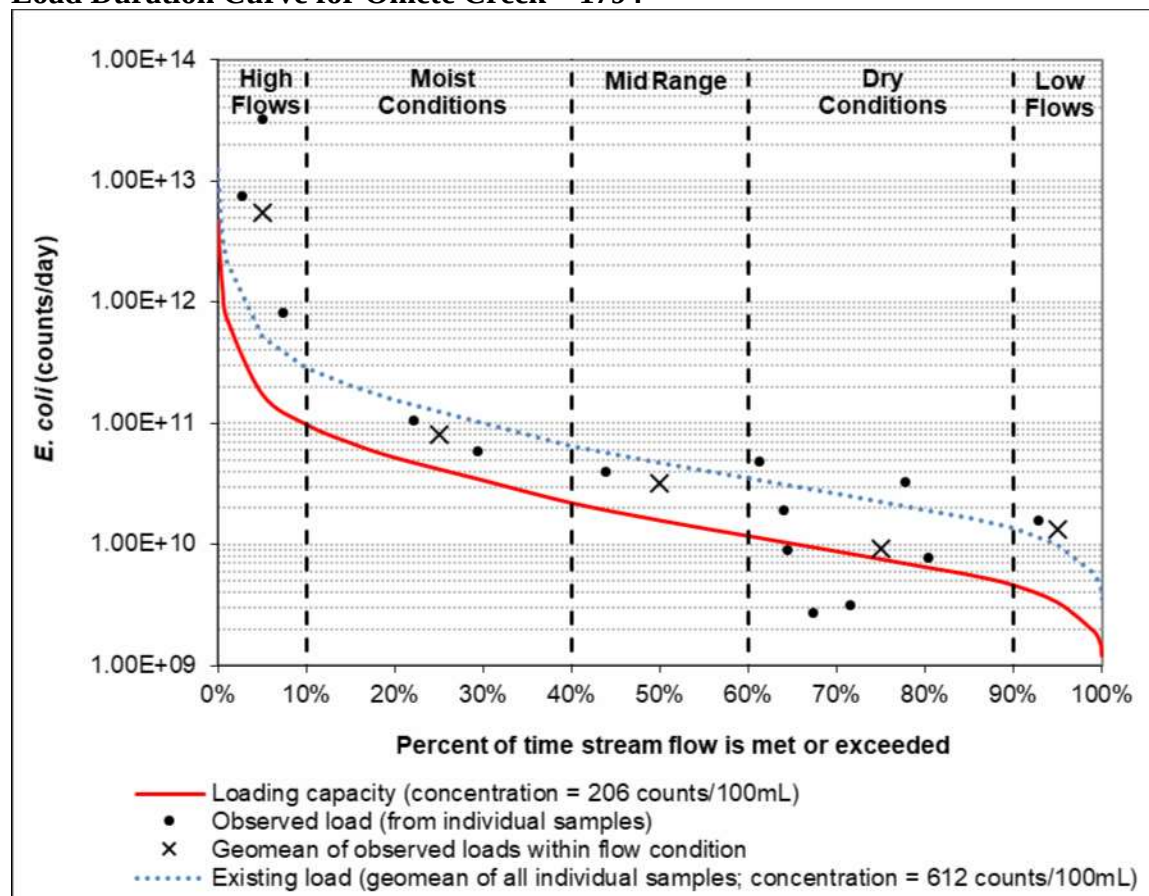


Figure 5.1.35 Load duration curve for Omete Creek, water body ID 1794

Table 5.1.34 Loads in Omete Creek (1794) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Loading Capacity (counts/day)	Existing Load (counts/day)
95	Low Flow	0.66	3.30E+09	9.82E+09
75	Dry Conditions	1.50	7.57E+09	2.25E+10
50	Mid Range	3.13	1.58E+10	4.68E+10
25	Moist Conditions	8.33	4.20E+10	1.25E+11
5%	High Flow	34.36	1.73E+11	5.15E+11

* Flows given in units of cubic feet per second (cfs).

Target *E. coli* concentration = 206 counts/100 mL

Overall needed *E. coli* reduction to attain water quality standards = 66 percent

There are no permitted point sources in the Omete Creek watershed.

Load Duration Curve for Brazeau Creek – 1796

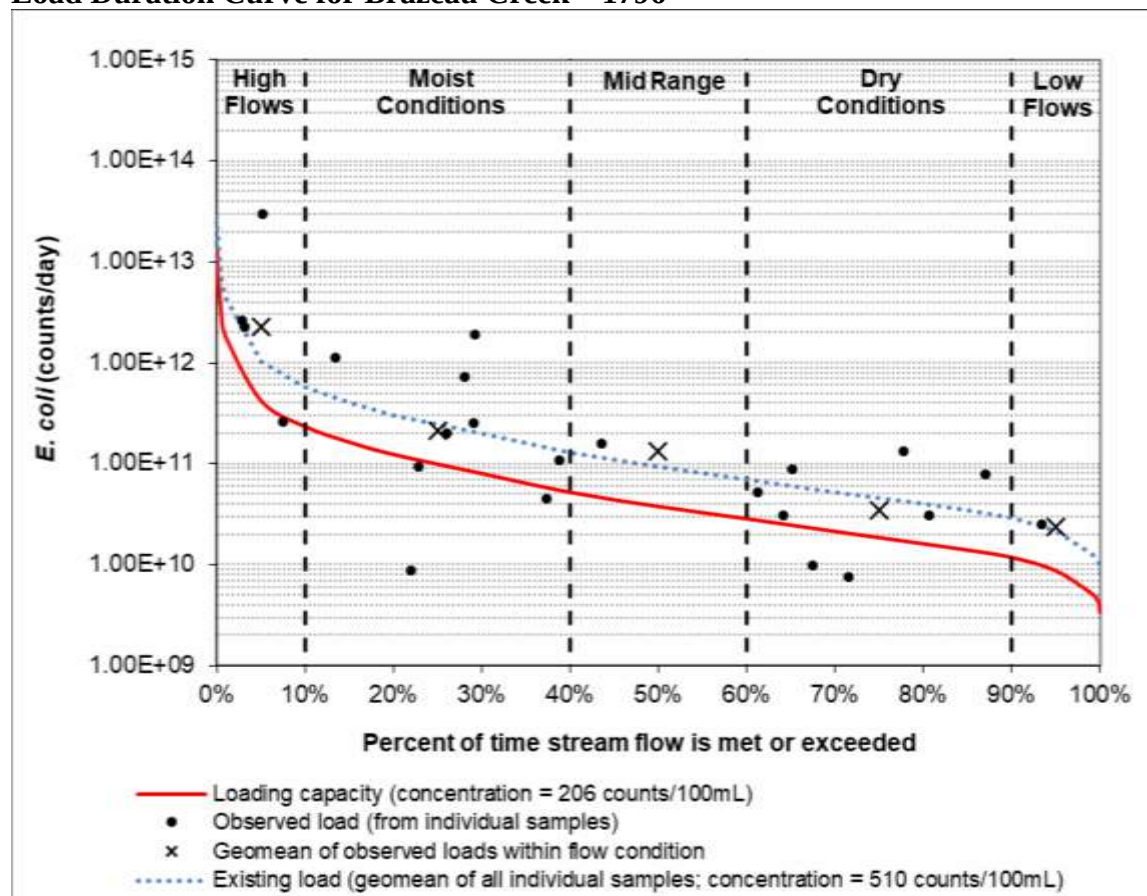


Figure 5.1.36 Load duration curve for Brazeau Creek, water body ID 1796

Table 5.1.35 Loads in Brazeau Creek (1796) at various flow conditions

Percent of time flow is met or exceeded	Flow Condition	Flow* (cfs)	Loading Capacity (counts/day)	Existing Load (counts/day)
95	Low Flow	1.71	8.63E+09	2.14E+10
75	Dry Conditions	3.66	1.84E+10	4.57E+10
50	Mid Range	7.44	3.75E+10	9.29E+10
25	Moist Conditions	19.63	9.89E+10	2.45E+11
5%	High Flow	83.31	4.20E+11	1.04E+12

* Flows given in units of cubic feet per second (cfs).

Target *E. coli* concentration = 206 counts/100 mL

Overall needed *E. coli* reduction to attain water quality standards = 60 percent

There is one municipal and domestic wastewater discharger in the watershed, which disinfects its effluent, and there are no CAFOs in this watershed. Facilities operating in compliance with site-specific industrial, general wastewater, or general stormwater permits are not expected to contribute bacteria loads above *de minimis* levels. For these reasons, point sources are not expected to contribute to the impairment and no pollutant reductions from point sources are necessary to achieve the specified loading targets.

Objective 5.1.4. Reduce nonpoint source nutrients, chemicals, and other hazardous materials from entering the PCK groundwater.

Strategy 5.1.4.1: Provide technical assistance and encourage proper handling, use, and disposal of chemical fertilizers, pesticides, herbicides, detergents, and other wastes.

Strategy 5.1.4.2: Develop a buyback program and/or collection program for unused chemicals and create a pesticide container deposit program to minimize the improper disposal of chemical containers and their contents.

Strategy 5.1.4.3: Promote and utilize cover crops, no till, and conservation tillage as a means to reduce soil loss through erosion and the potential for any pollutant tied to the soil from entering the groundwater.

Strategy 5.1.4.4: Provide technical assistance to pesticide applicators about the guidelines set forth on pesticide labels and ensure that they are followed and understood to be the law. In addition, provide training to all applicators within PCK on safe, efficient application of surface applied chemicals within a karst area.

Strategy 5.1.4.5: Conduct sinkhole cleanouts of trash laden areas using cost-share initiatives to reduce leaching materials.

GOAL 5.2. Monitor the abundance and distribution of the Grotto Sculpin population; while, documenting karst biodiversity in the surface and subsurface streams within the PCK watershed.

Rationale: Perry County is known for its high density of sinkholes and caves. Due to the rate that NPS pollutants enter and move through the PCK region, as documented by Moss and Pobst 2010 dye traces, it will be imperative that continued monitoring of cave dwelling organisms be conducted. The MDC is monitoring, researching and documenting Grotto Sculpin population trends. Grotto Clubs in the area are continually conducting cave surveys and can be a valuable partner in collecting addition data on other cave organisms. Stream Teams and other volunteer groups can assist with collections of surface macroinvertebrates. Monitoring macroinvertebrates within the PCK watershed could provide insight into water quality conditions as many are considered indicator species. Conducting routine bio assessments of surface and subsurface waters are a vital tool while documenting changes within these communities.

Objective 5.2.1: Monitor Grotto Sculpin population trends across their range within the PCK watershed.

Strategy 5.2.1.1: Utilizing national and state agency staff, document Grotto Sculpin population trends by sampling karst habitats within the species range as designated by the USFWS.

Strategy 5.2.1.2: Utilize the MDC Resource Science Division Research Proposal Process as a means to garner valuable information to help assess Grotto Sculpin population trends.

Objective 5.2.2: Monitor aquatic macroinvertebrates in PCK watershed as these are good indicators of water quality.

Strategy 5.2.2.1: Use Stream Teams and other volunteers to conduct surveys at various sites across the PCK landscape to determine biodiversity.

Objective 5.2.3: Inventory and monitor cave life throughout PCK focusing on areas where Grotto Sculpin reside.

Strategy 5.2.3.1: Utilize local volunteers groups and grotto clubs to collect pertinent inventory data and specific counts on cave life within PCK.

Strategy 5.2.3.2: Require that all data collected by volunteer groups or government agencies be stored in the Missouri Cave Database.

GOAL 5.3. Educate and improve PCK stakeholder awareness about groundwater movement and sources of pollutants impacting the PCK watershed.

Rationale: Educating stakeholders in the PCK region will be a priority. It will be essential to inform the public about the karst landscape they live in, how karst ecosystems function and how groundwater moves through these areas. In addition to ecosystem function, it will be important to inform the public about unique cave diversity and how impacts from poor land management are impacting karst habitats. It is important that state and federal agencies share this information with local stakeholders. This will lead to an understanding and appreciation for the karst resources and will begin to develop and build future relationships within the community. By increasing outreach and education; while, cooperating with the local groups, landowners, caving enthusiasts, city and county officials; we can deliver a unified message about water quality, streams, sinkholes, vertical drainpipes, land management practices and potential cost-share initiatives.

Objective 5.3.1: Engage both urban and rural residents within the PCK through various media outlets promoting karst management and protection.

Strategy 5.3.1.1: Develop and distribute brochures, fliers, and other media (i.e., newspaper, newsletters, and radio) which promotes karst management and water quality improvement throughout PCK.

Strategy 5.3.1.2: Increase educational signage within the urban and rural areas of the PCK watershed to emphasize groundwater pathways and associated risks with water

quality in karst habitats. Billboard advertisements, gas pump placards, and restaurant placemats could be examples of advertisement opportunities.

Strategy 5.3.1.3: Utilize various social media outlets (i.e., Facebook, Twitter, YouTube, etc.) to post upcoming events, issues, and accomplishments within the PCK. In addition, a webpage could be used to post literature and other important information regarding PCK.

Objective 5.3.2: Provide pertinent forums for community outreach and education to be discussed regarding PCK management, protection, and progress.

Strategy 5.3.2.1: Continue interagency support to provide presentations, workshops, or technical advice to the stakeholders of PCK regarding karst related issues.

Strategy 5.3.2.2: Acquire agreements with landowners to demonstrate successful implementation of karst BMPs.

IMPLEMENTATION PROGRAM

Section 6. IMPLEMENTATION, MILESTONES, AND PERFORMANCE

The Perry County community involvement is critical to successful watershed planning and implementation of BMPs and other protection strategies. Input from citizens, community leaders, local government staff, and other stakeholders will be a major component of the PCK Watershed Project. Building support for the protection of PCK watershed will require a major educational effort directed at the stakeholders, developers, and government personnel. Further successes will be dependent on the implementation of BMPs. The community will also need to be cognizant of current septic issues and begin to lay the groundwork for addressing and reducing impairments.

Utilizing this plan, federal, state and local government agencies can and should apply for future Section 319 grants to monitor nonpoint source pollution to the surface and subsurface streams within the PCK watershed. Depending on available funds, monitoring could be conducted on either a coarse or fine scale to determine overall and localized impairment changes. Water quality monitoring should be implemented in conjunction with this plans approval and should follow at minimum the recommended monitoring regime discussed in Section 8. Setting milestones and performance measures we can adaptively change and redirect our efforts as improvements or impairments are discovered on the landscape as well as keeping the PCCEEC on target with their accomplishments. As such, milestones are subject to modification as the plan is implemented.

Goals & Strategies	Priority Level	Potential Partners (Leads are in bold)	Technical Assistance Required	Estimated Financial Requirements	Implementation				
					Year 1	Year 2	Year 3	Year 4	Year 5-10
5.1 Improve water quality throughout the PCK watershed 5.1.1.1 Collect water physical water quality data	1	MDC MDNR PCSWCD City of Perryville Perry County Commission	MDNR MDC	\$5000/data sonde—need minimum of 4	X	X			X
5.1.1.2 Collect monthly grab samples analyzing physical and chemical water quality constituents	1	MDC MDNR PCSWCD City of Perryville Perry County Commission Stream Teams Grotto Clubs	MDNR MDC	\$100/sample \$4800/year/sample	X	X			X
5.1.1.3 Use POCIS and SPMDs to collect data as was previously done in the Section 319 grant and Fox et al. 2010 study	1	MDC MDNR PCSWCD City of Perryville Perry County Commission	MDNR MDC	Unknown	X	X			X
5.1.2.1 Assess and prioritize groundwater inputs	1	City of Perryville Perry County Commission PCSWCD MDC	Regional Planning MDC PCSWCD MSS/CRF	Unknown	X	X	X	X	
5.1.2.2 Implement cost share BMPs to reduce sediment transport	1	USFWS MDC PCSWCD NRCS City of Perryville Perry County Commission	USFWS MDC PCSWCD NRCS	N/A	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing

5.1.2.3 Manage public lands as good examples of proper karst management	1	MDC L-A-D Foundation City of Perryville	MDC USFWS	N/A	On- goin g	On- goin g	On- goin g	On- goin g	On- going
5.1.2.4 Identify alternative BMPs to be used in urban areas around groundwater inputs	2	USFWS MSS/CRF MDC USGS City of Perryville Perry County Commission	USGS MDC MSS/CRF	N/A					X
5.1.2.5 Implement proper buffer widths in accordance with partner agency specifications around groundwater inputs	1	City of Perryville Perry County Commission MDC USFWS PCSWCD NRCS	MDC USFWS PCSWCD NRCS	N/A	On- goin g	On- goin g	On- goin g	On- goin g	On- going
5.1.2.6 Implement city ordinances to protect groundwater inputs	1	City of Perryville	USFWS MDNR	N/A	X				
5.1.2.7 Remove and repair malfunctioning vertical drainpipes	2	City of Perryville Perry County Commission MDC L-A-D Foundation PCFB PCSWCD	USGS USFWS MDC PCSWCD	TBD					X
5.1.3.1 Assess septic systems within the major recharge areas in PCK	1	PCHD MDNR Perry County Commission	MDNR	TBD	X	X	X	X	
5.1.3.2 Establish a monitoring program for septic systems in PCK	3	PCHD MDNR	MDNR	TBD					X

		<i>Perry County Commission</i>							
5.1.3.3 Use cost-share funds and other funding sources to address inadequate or malfunctioning septic systems in the PCK	2	PCHD MDNR <i>Perry County Commission</i>	MDNR	TBD				X	X
5.1.3.4 Develop programs to assist with septic system maintenance	2	PCHD MDNR <i>Perry County Commission</i>	MDNR	TBD				X	X
5.1.3.5 Implement BMPs for livestock to reduce animal introduced E. coli	1	PCSWCD NRCS USFWS MDC PCFB MuExt	MDC PCSWCD NRCS USFWS	N/A	On- goin g	On- goin g	On- goin g	On- goin g	On- going
5.1.4.1 Provide technical assistance with handling and disposal of chemicals in PCK		NRCS PCSWCD MuExt PCFB <i>Perry County Commission</i> Mo Dept of Ag	<i>Perry County Commission</i> MuExt PCSWCD Mo Dept Of Ag	N/A	On- goin g	On- goin g	On- goin g	On- goin g	On- going
5.1.4.2 Develop a buy back or collection program for unused or unwanted chemicals in PCK		PCFB <i>Perry County Commission</i> MuExt Mo Dept of Ag PCSWCD NRCS	<i>Perry County Commission</i> MuExt PCSWCD Mo Dept Of Ag	TBD		X		X	X
5.1.4.3 Promote agricultural BMPs to reduce soil loss thus reducing potential pollutants tied to the soil entering PCK groundwater	1	PCSWCD NRCS MuExt PCFB <i>Perry County Commission</i> MDC	MDC PCSWCD NRCS USFWS	N/A	On- goin g	On- goin g	On- goin g	On- goin g	On- going

		USFWS							
5.1.4.4 Provide technical assistance to pesticide applicators on proper application in karst systems following label guidelines	1	PCFB Mo Dept of Ag MuExt PCSWCD NRCS Perry County Commission	MuExt PCSWCD NRCS	N/A	On-going	On-going	On-going	On-going	On-going
5.1.4.5 Conduct sinkhole cleanouts of trash laden areas	1	USFWS MDC PCSWCD NRCS City of Perryville Perry County Commission	MDC USFWS PCSWCD NRCS	~3,000/ sinkhole cleanout	On-going	On-going	On-going	On-going	On-going
5.2 Monitor abundance and distribution of Grotto Sculpin and other karst biodiversity in the surface and subsurface streams in PCK 5.2.1.1 Monitor Grotto Sculpin population trends across their range in PCK	1	MDC USFWS MDNR MSS/CRF	MDC USFWS	Agency funded	X	X			X
5.2.1.2 Utilize MDC Resource Science Division research proposal process to garner valuable information to understand Grotto Sculpin trends		MDC	MDC USFWS	TBD					X
5.2.2.1 Use Stream Team and other volunteers to conduct surveys in the PCK landscape to shows trends over time in aquatic macroinvertebrates		MDC MDNR Stream Team Perry County Commission City of Perryville	MDC Stream Team	TBD		X		X	X
5.2.3.1 Inventory cave life by utilizing local volunteers and grotto clubs	2	MDC Stream Team MSS/CRF	MDC MSS/CRF	Agency funded	X	X			X
5.3 Provide technical assistance through outreach and education efforts to improve PCK stakeholders awareness of impairments in the PCK	1	NRCS PCSWCD MuExt MDC USFWS	MDC USFWS NRCS PCSWCD	Unknown		X		X	X

5.3.1.1 Develop brochures, fliers, and other media to promote proper karst management and water quality in PCK		City of Perryville Perry County Commission	MuExt MSS/CRF						
5.3.1.2 Increase educational signage within the urban and rural areas of PCK about Grotto Sculpin, groundwater movement, and karst resource protection	1	NRCS PCSWCD MuExt MDC USFWS City of Perryville Perry County Commission	MDC USFWS NRCS PCSWCD MuExt MSS/CRF	Unknown	X	X			X
5.3.1.3 Utilize social media to post upcoming events, issues, and accomplishments within the PCK	1	NRCS PCSWCD MuExt MDC USFWS City of Perryville Perry County Commission	MDC USFWS NRCS PCSWCD MuExt MSS/CRF	Unknown	On-going	On-going	On-going	On-going	On-going
5.3.2.1 Provide interagency presentations, workshops, and technical advice to PCK stakeholders regarding PCK management	2	NRCS PCSWCD MuExt MDC USFWS City of Perryville Perry County Commission	MDC USFWS NRCS PCSWCD MuExt MSS/CRF	TBD			X		X
5.3.2.2 Acquire agreements with landowners to demonstrate successful implementation of BMPs	2	NRCS PCSWCD MuExt MDC USFWS Perry County Commission	MDC USFWS NRCS PCSWCD MuExt MSS/CRF	TBD		X			X

Performance will be documented as strategies are implemented. It will be strongly encouraged by the PCCEEC as well as the state and federal partners to continue to document each and every accomplishment no matter the size. As milestones are achieved adaptive management will most likely occur in order to keep all the partners moving in the right direction. Education will be a major component of this plan moving forward. Holding pertinent educational events will help disseminate this plans goals and objectives into the future. Getting landowner buy in will be key to the success of this plan. With the inventories stated earlier in this section, we can most certainly target the stakeholders and areas in need to begin to address water quality impairments. Several sites within the PCK can and should be used as demonstration sites for outreach and education. Cost-share monies are already on the ground and projects such as trash sinkhole cleanouts and fencing exclusions on sinkholes are in motion. Many of the milestones mentioned above should be started, if not completed, within the first five years of this plan being accepted and approved and a 5-10 year review of this document should be conducted to ensure that we are focused in our future efforts. The USFWS will conduct a five year review of their endangered species listing in 2018. Much of these strategies should be in full force and with the implementation of the monitoring component trends should become evident throughout the PCK watershed within the next 10 to 15 years.

Implementation of the goals and strategies can be conducted in a multitude of ways. First of all, prior studies have identified several recharge areas within the PCK watershed. These also coincide with grotto sculpin locations. These could be considered high priority areas; however, MoDNR has identified 12-digit HUCs where 303(d) impairments have been identified for *E. coli*. The 12-digit HUCs also include several of the resurgence/springs where water quality concerns were noted in Section 4. The maps on the following pages present critical areas for nonpoint source pollutant loading and are based on areas of agricultural land use that are located on soils with the highest potential for runoff. Additional focus was given to riparian areas where impacts from pollutant loading may be more direct. These areas were broadly determined based on available geographic information system (GIS) data, but should be supplemented with local knowledge of the watershed in order to appropriately select and site BMPs. The 12-digit HUCs presented include:

- 071401050301 Bois Brule Creek
- 071401050302 Dry Fork
- 071401050303 Puckett Island
- 071401050304 Omete Creek
- 071401050305 Cinque Hommes Creek
- 071401050308 Brazeau Creek

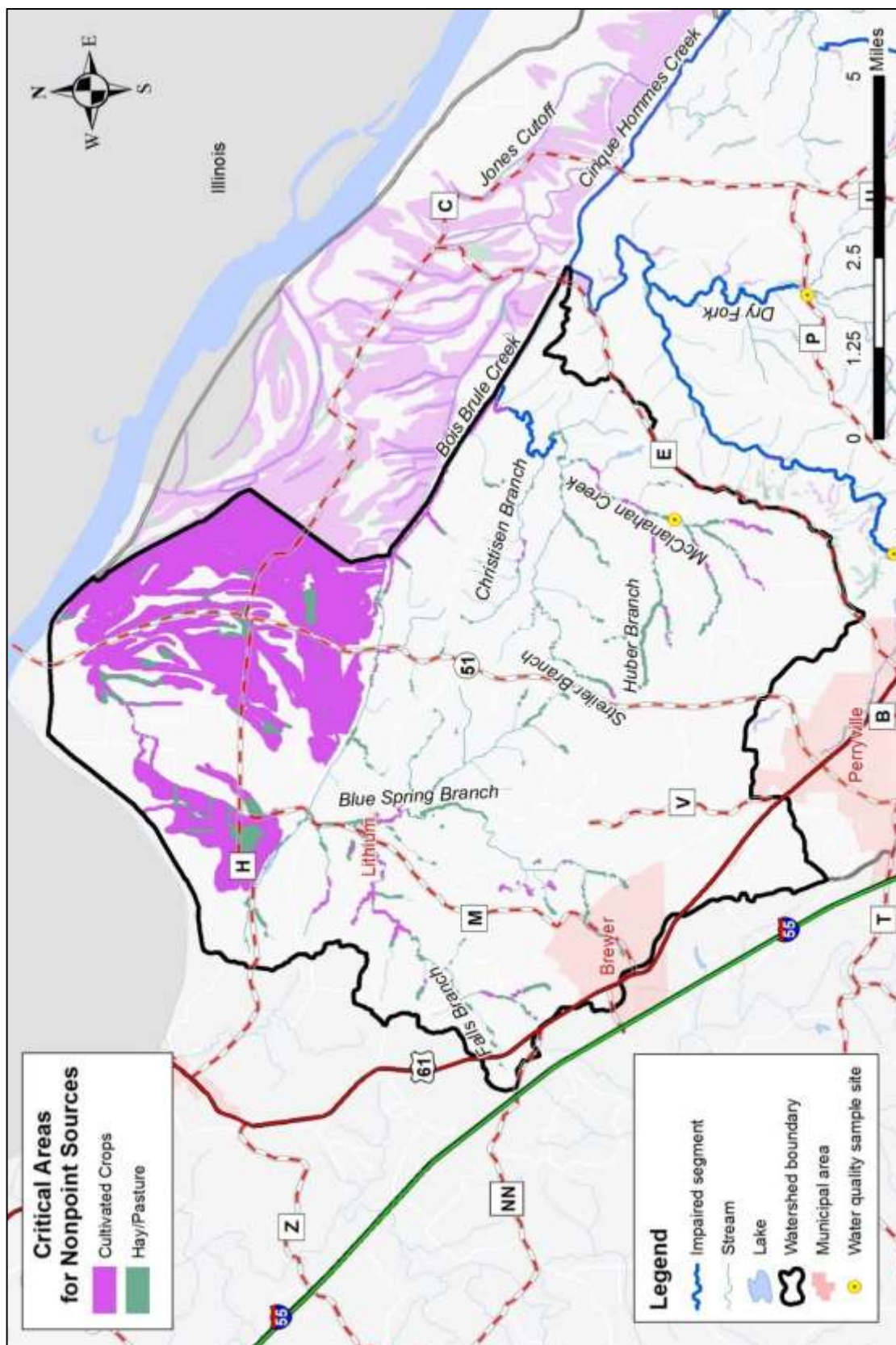


Figure 6.1. HUC 071401050301 – Bois Brule Creek

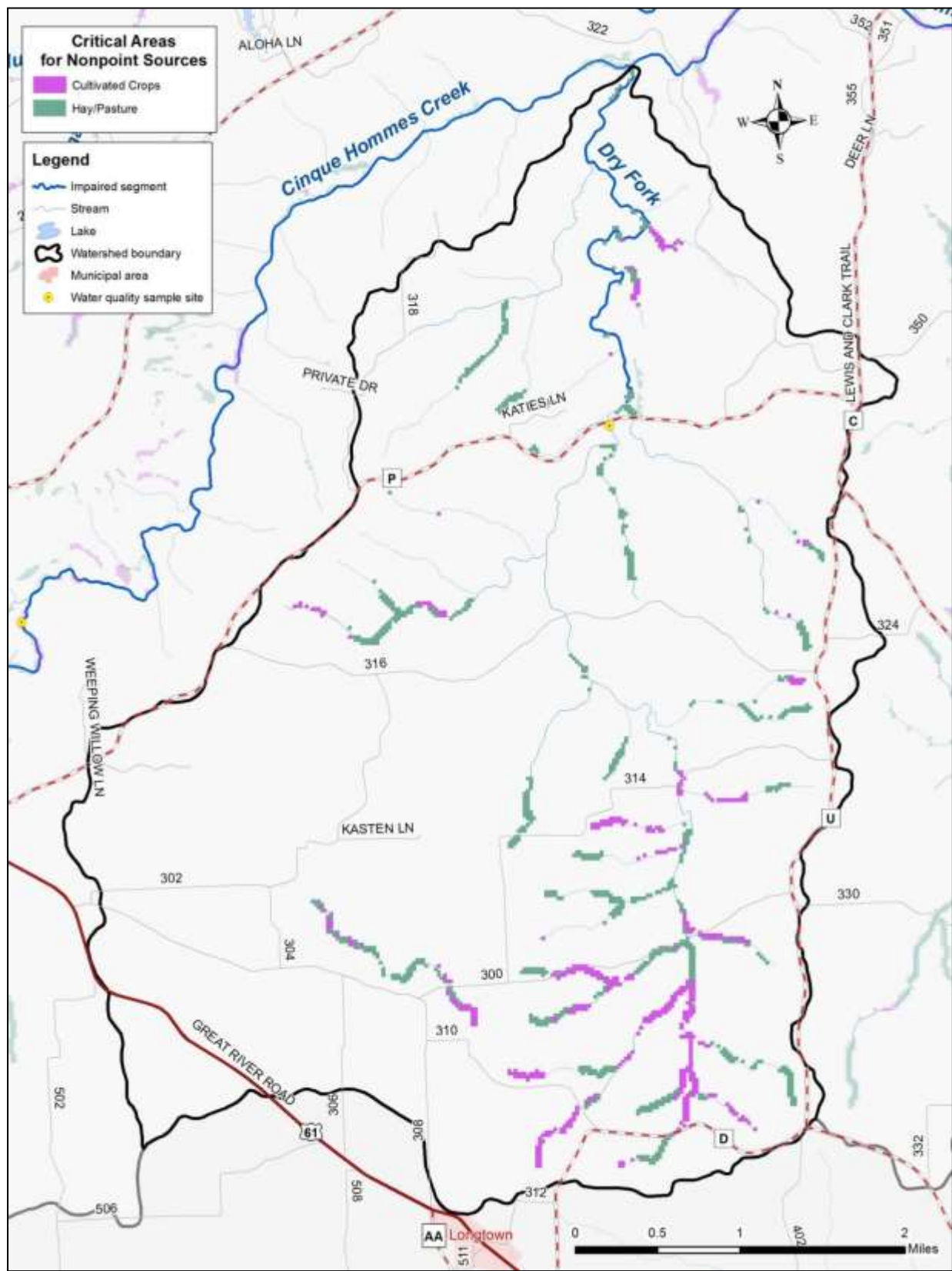


Figure 6.12. HUC 071401050302 – Dry Fork

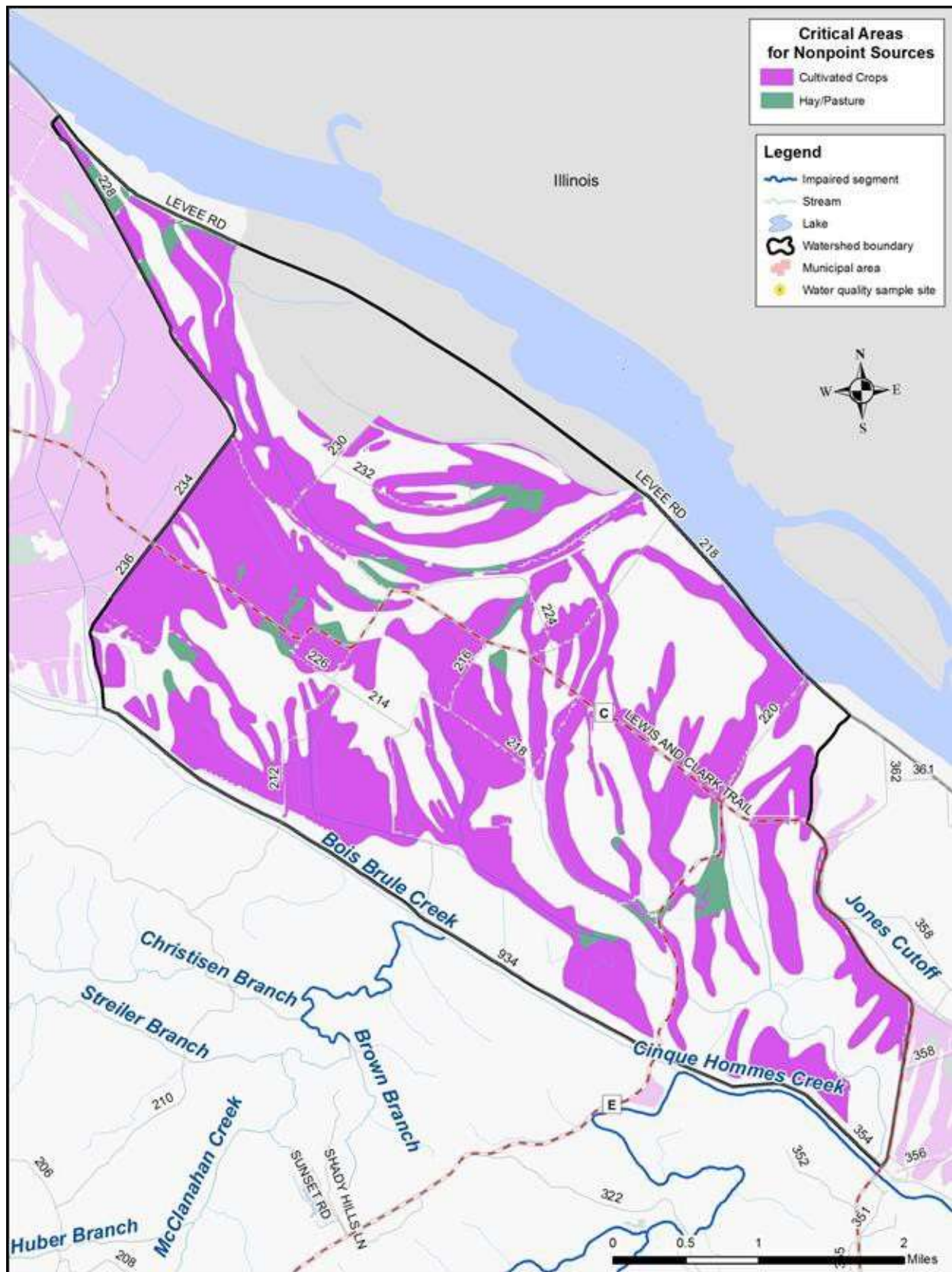


Figure 6.13. HUC 071401050303 – Puckett Island

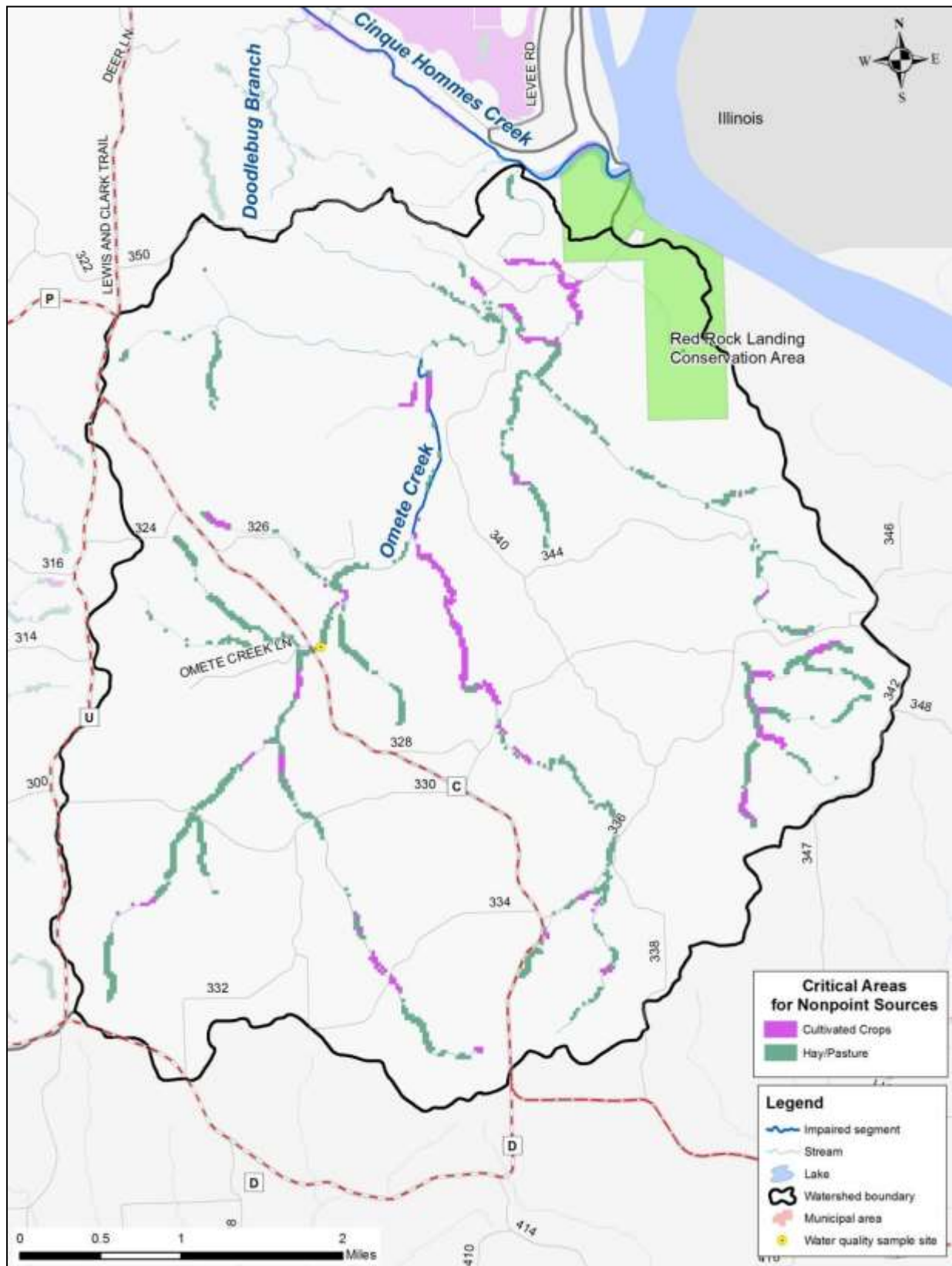


Figure 6.14. HUC 071401050304 – Omete Creek

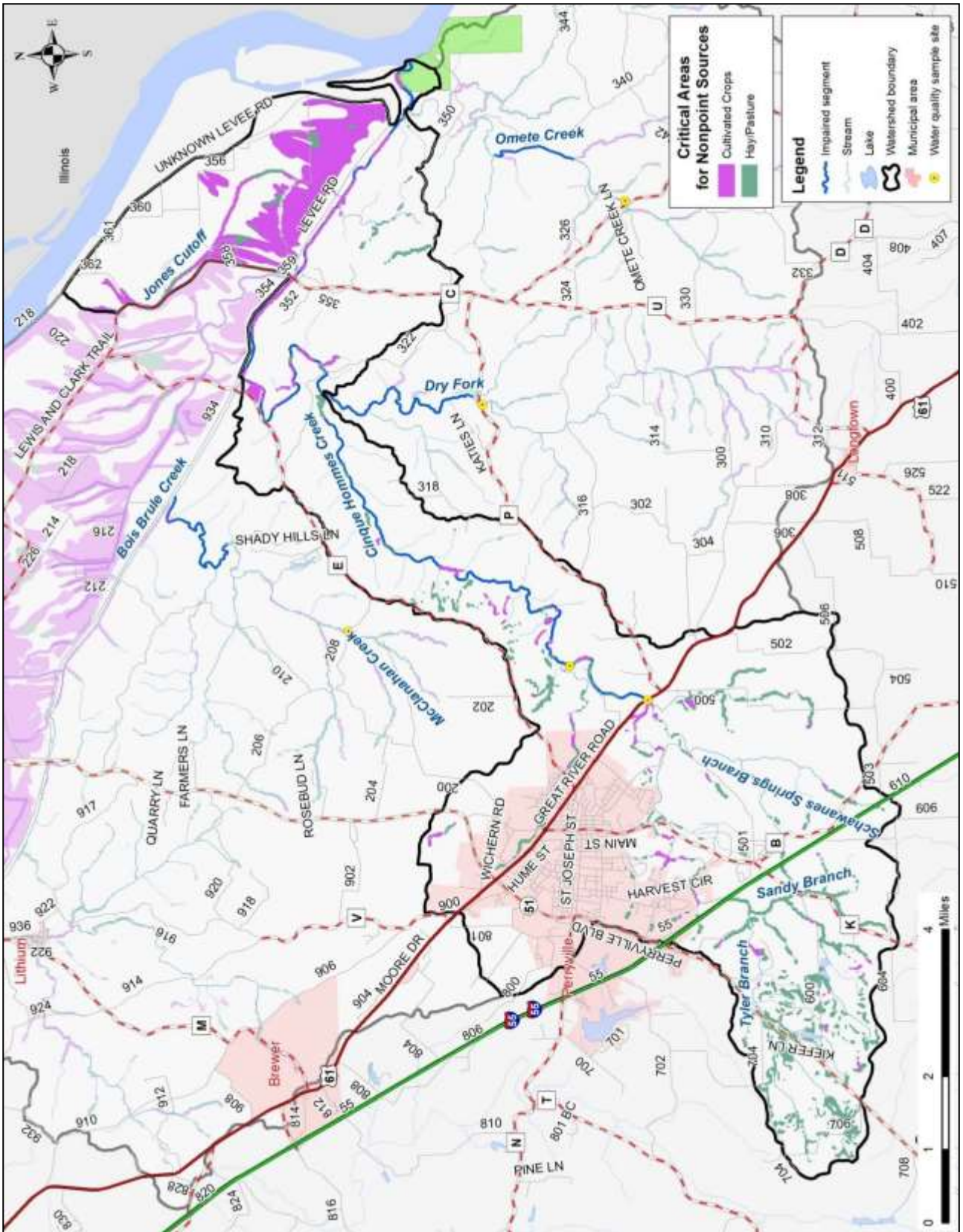


Figure 6.15. HUC 071401050305 – Cinque Hommes Creek

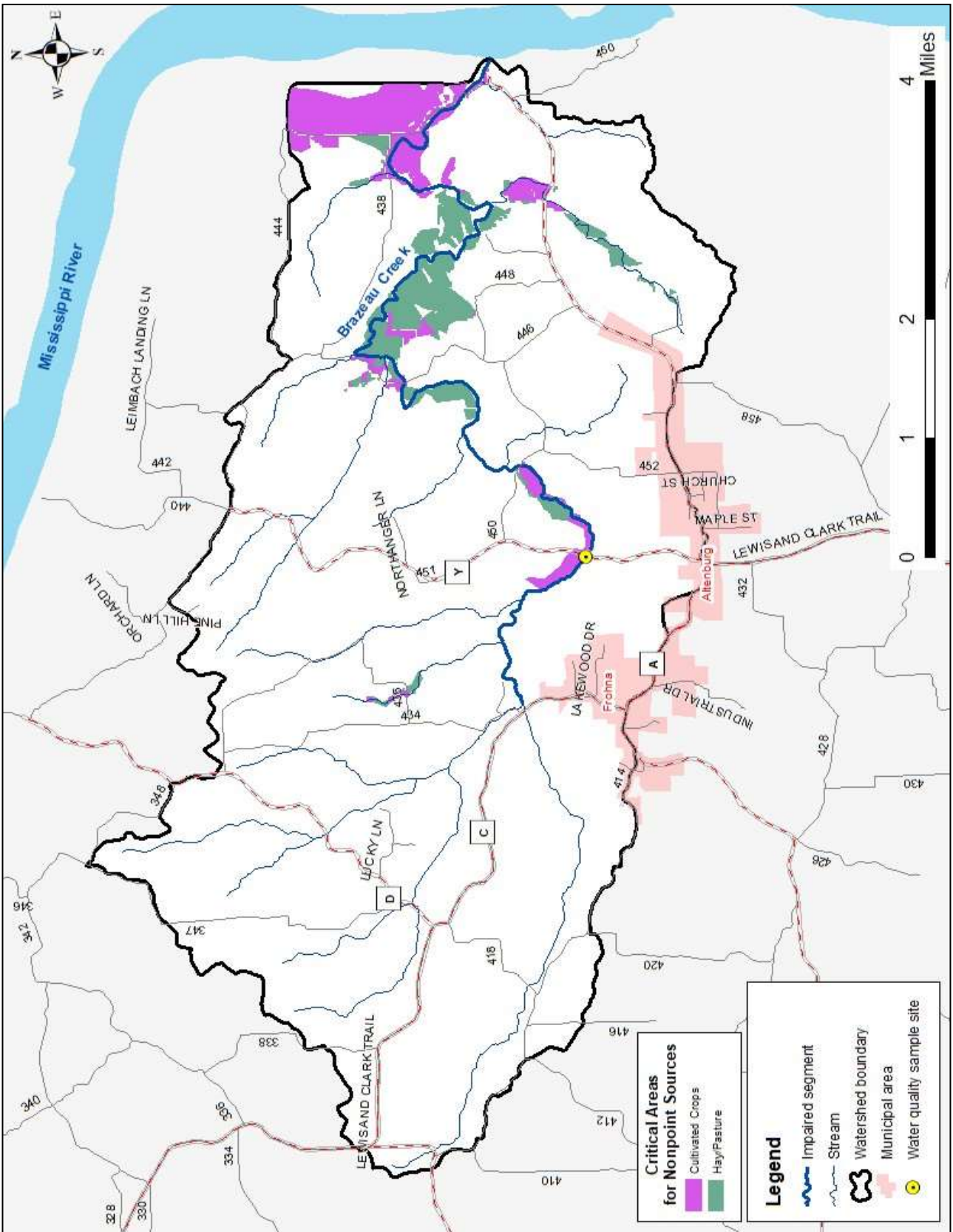


Figure 6.16. HUC 071401050308 – Brazeau Creek

Section 7. FINANCIAL & TECHNICAL ASSISTANCE

Successful implementation of the goals, objectives and strategies (presented in Section 5) will require financial and technical support from both state and federal funding sources as well as public and private organizations. This plan has identified impairments throughout the PCK watershed in addition to management strategies for achieving load reductions. This collaborative effort between the community, the PCCEEC, and state and federal agencies is vital to ensure a successful plan approach.

Technical assistance for the goals and objectives will be provided by numerous agencies currently partnered with the PCCEEC. The PCSWCD and NRCS are located in Perryville and have dedicated technicians who can advise and administer various programs utilizing state and federal funds for a whole host of BMPs and land management activities (i.e., Environmental Quality Incentives Program (EQIP), CRP, CCRP). The USFWS and MDC have dedicated private lands biologists who are willing to aid and assist any landowner to utilize funds from their state and federal budgets. In addition to these entities, the City of Perryville, Perry County Commission, and local businesses can aid in the implementation of BMPs as well as sponsoring and holding education events to help disseminate information to the stakeholders of Perry County.

Financial assistance will be available through the aforementioned entities and programs, but to have a successful watershed plan additional funds will need to be acquired to implement a full scale approach.

Current Programs

PCSWCD administers their programs on a more local level. They offer assistance to only landowners and signups are conducted anytime during the budgeted year. Cost-share funds cover 75% of the project cost up to a \$12,000 cap each year. The other 25% of the project cost plus any additional costs above the \$12,000 cap are the responsibility of the landowner. The cap does not apply to Animal Waste Management or Irrigation Management. All projects do require a mandatory maintenance period during which the landowner agrees to maintain the project according to NRCS specifications. Projects are randomly spot checked during this maintenance period to ensure the project is in compliance with NRCS specifications. Cost-share funds are currently available for the following practices (see swcd.mo.gov/perry/assistance.htm for detailed explanation of program and practices):

Animal Waste Management

- N312 Beef Waste Management

Irrigation Management

- N554 Drainage Water Management

Woodland Erosion

- N472 Woodland Livestock Exclusion

Sensitive Area

- BDSP-31 Buffer Sinkhole Improvement
- DSP- 31 Sinkhole Improvement to Control Gully Erosion

- N386 Field Border
- N391 Riparian Forest Buffer
- N574 Spring Development
- N725 Sinkhole Treatment
- WQ10 Stream Protection

Sheet and Rill/Gully Erosion

- DSL-44 Terrace Systems with Tile
- DSL-5 Diversion
- DSL-11 Permanent Vegetation Cover on Critical Areas
- DWC-1 Water Impoundment Reservoirs
- DWP-1 Sediment Retention, Erosion or Water Control Structures
- DWP-3 Grassed Waterways

NRCS is responsible for administering programs in the Farm Bill. Most of this is through the EQIP program. EQIP provides financial and technical assistance to agricultural producers (which could be defined as agricultural production or forestry management) to plan and implement conservation practices that are geared towards improving soil, water, plant, animal, air and other related natural resources. This program is a competitive program and landowners are given points depending on what conservation practice, how much, and how long they want to enter into the practice. Signups for this program are on a continuous basis however contracts submitted after November 20 of the given year will be considered for funding the next year. The following are current available practices under general EQIP (see http://www.nrcs.usda.gov/wps/portal/nrcs/main/mo/programs/financial/eqip/#General_Fund for a detailed explanation of program and practices):

- 472 Access Control
- 316 Animal Mortality Facility
- 314 Brush Management
- 102 Comprehensive Nutrient Management Plan
- 327 Conservation Cover
- 328 Conservation Crop Rotation
- 340 Cover Crop
- 342 Critical Area Planting
- 362 Diversion
- 554 Drainage Water Management
- 130 Drainage Water Management Plan
- 647 Early Successional Habitat Development and Management
- 108 Feed Management Plan
- 382 Fence
- 386 Field Border
- 394 Firebreak
- 142 Fish and Wildlife Habitat Management Plan
- 512 Forage and Biomass Planting
- 102 Forest Management Plan
- 666 Forest Stand Improvement

- 655 Forest Trails and Landings
- 410 Grade Stabilization Structure
- 412 Grassed Waterway
- 110 Grazing Management Plan
- 561 Heavy Use Area Protection
- 315 Herbaceous Weed Control
- 595 Integrated Pest Management
- 114 Integrated Pest Management Plan
- 464 Irrigation Land Leveling
- 430 Irrigation Pipeline
- 443 Irrigation System- Surface and Subsurface
- 449 Irrigation Water Management
- 118 Irrigation Water Management Plan
- 516 Livestock Pipeline
- 484 Mulching
- 590 Nutrient Management
- 104 Nutrient Management Plan
- 146 Pollinator Habitat Enhancement Plan
- 378 Pond
- 521B Pond Sealing or Lining – Soil Dispersant
- 338 Prescribed Burning
- 112 Prescribed Burning Plan
- 528 Prescribed Grazing
- 533 Pumping Plant
- 329 Residue and Tillage Management, No Till
- 390 Riparian Herbaceous Cover
- 367 Roofs and Covers
- 646 Shallow Water Development and Management
- 574 Spring Development
- 442 Sprinkler System
- 578 Stream Crossing
- 587 Structure for Water Control
- 649 Structures for Wildlife
- 606 Subsurface Drain
- 600 Terrace
- 612 Tree/Shrub Establishment
- 490 Tree/Shrub Site Preparation
- 620 Underground Outlet
- 645 Upland Wildlife Habitat Management
- 630 Vertical Drain
- 360 Waste Facility Closure
- 632 Waste Separation Facility
- 313 Waste Storage Facility
- 634 Waste Transfer

- 638 Water and Sediment Control Basin
- 642 Water Well
- 614 Watering Facility
- 351 Well Decommissioning
- 657 Wetland Restoration
- 380 Windbreak/Shelterbelt Establishment

The Regional Conservation Partnership Program (RCPP) is restoring glades and woodland communities for threatened species in the Ozarks of Southeast Missouri. This funding source falls under EQIP but allows partners in aid in conservation practice payments. Within PCK this will allow MDC to pay an additional 20% on top of the current EQIP payment within these critical areas upon completion of the practice. The following are the current available practices under RCCP (see

<http://www.nrcs.usda.gov/wps/portal/nrcs/detail/mo/programs/farmbill/rcpp/?cid=stelprdb1253276> for a detailed explanation of program and practices:

- 472 Access Control
- 314 Brush Management
- 327 Conservation Cover
- 340 Cover Crop
- 342 Critical Area Planting
- 647 Early Successional Habitat Development and Management
- 382 Fence
- 386 Field Border
- 394 Firebreak
- 512 Forage and Biomass Planting
- 666 Forest Stand Improvement
- 655 Forest Trails and Landings
- 410 Grade Stabilization Structure
- 412 Grassed Waterway
- 315 Herbaceous Weed Control
- 484 Mulching
- 338 Prescribed Burning
- 578 Stream Crossing
- 649 Structures for Wildlife
- 612 Tree/Shrub Establishment
- 490 Tree/Shrub Site Preparation
- 620 Underground Outlet
- 645 Upland Wildlife Habitat Management
- 638 Water and Sediment Control Basin

Conservation Reserve Program (CRP) is a land retirement program which pays annual rental payments for 10 to 15 years and is administered by the Farm Service Agency with NRCS providing eligibility, planning, and implementation. Under CRP, there are two designations of

continuous CRP (CCRP) or general CRP. The focus of this program is on water quality and erosion and many of the practices emphasize riparian buffers and filter strips. General CRP signups are held periodically and are competitive while CCRP are available anytime and are not competitive.

The Partnerships for Fish and Wildlife Program is administered by the USFWS and provides financial and technical assistance to restore habitat on private lands. It is primarily to restore habitats for listed species and migratory birds, to keep common species common, to complement National Wildlife Refuges, and to prevent habitat fragmentation. This program requires a 10 year agreement and prioritizes habitats which include wetland, upland, and riparian/stream.

The Cooperative Endangered Species Conservation Fund provides financial assistance for a wide array of conservation projects for candidate, proposed, and listed species. This grant fund is authorized under Section 6 of the Endangered Species Act and can be awarded to private landowners and groups for conservation projects. These funds can be solicited on a yearly basis but are competitive.

Landowner Assistance Program (LAP) is administered by the MDC private lands biologists on a yearly basis. This program is used primarily when projects are small or time sensitive. Cost-share rates range from 50-75% of project costs not to exceed \$6,000 per year. This program cannot be used on multiple year projects as it is based on fiscal year budgets.

The Habitat Challenge Grants are offered by non-government organizations (NGO's; i.e., National Wild Turkey Federation, Quail Forever, Ducks Unlimited, etc.) in cooperation with the MDC for selected LAP practices. These payments are typically 50/50 split between organizations and can be helpful when LAP regional funds are limited.

Stream Stewardship Trust Fund program is administered by the Missouri Conservation Heritage Foundation from a voluntary in-lieu fee mitigation program to which developers can make payments to meet requirements of Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. Projects funded by this program must be endorsed and submitted by the MDC. Projects that are likely to be funded include, but are not limited to, those having financial support from other agencies or partners, address targeted conservation needs either in and a Conservation Opportunity Area (COA), priority stream or watershed, or areas with high outdoor recreational potential. Payments and overall program implementation vary depending on the practice.

Table 7.1. Missouri Department of Natural Resources suggested Agricultural Best Management Practices provided by the Missouri Soil and Water Conservation Program to address impairment issues in Perry County Karst Watershed.

Missouri Soil and Water Conservation Program		Practice Mode of Action*			Pollutants Addressed			
Resource Concerns and Associated Cost-Share Practices		Avoid	Control	Trap	Sediment	Nutrients	E. coli	Pesticide
SWCP Cost-Share #	Sheet/Rill and Gully Erosion	Sheet/Rill and Gully Erosion						
DSL-01	Permanent Vegetative Cover Establishment	X	X	X	X	X	X	X
DSL-02	Permanent Vegetative Cover Improvement	X	X	X	X	X	X	X
DSL-04	Terrace System		X	X	X	X		X
DSL-44	Terrace System with Tile		X		X	X		
DSL-05	Diversion		X		X	X		X
DSL-11	Permanent Vegetative Cover - Critical Area	X	X	X	X	X		X
DSL-111	Permanent Vegetative Cover - Critical Area: Confined Animal Feedlot	X	X	X	X	X	X	
DSL-15	No-Till System	X	X	X	X	X		X
DWC-01	Water Impoundment Reservoir		X	X	X	X		X
DWP-01	Sediment Retention, Erosion or Water Control Structure		X	X	X	X		X
DWP-03	Sod Waterway	X	X	X	X	X		X
N332	Contour Buffer Strips	X	X	X	X	X		X
N340	Cover Crop	X	X	X	X	X	X	X
N380	Windbreak/Shelterbelt Establishment	X	X	X	X	X		X
N410	Drop Pipe		X	X	X	X		
N585	Contour Stripcropping		X	X	X	X	X	X
Cost-Share #	Grazing Management	Grazing Management						
DSP-02	Permanent Vegetative Cover Enhancement	X	X	X	X	X	X	
DSP 3.1	Grazing System Water Development		X		X	X	X	
DSP 3.2	Grazing System Water Distribution		X		X	X	X	
DSP 3.3	Grazing System Fence	X	X		X	X	X	

DSP 3.4	Grazing System Lime		x			x		
DSP 3.5	Grazing System Seed	x	x	x	x	x	x	
	-							
Cost-Share #	Irrigation Management	Irrigation Management						
N430	Irrigation Water Conveyance		x		x	x		x
N442	Irrigation System, Sprinkler	x			x	x		x
N443	Irrigation System, Surface and Subsurface		x		x	x		x
N447	Irrigation System, Tail Water Recovery		x		x	x		x
N554	Drainage Water Management		x	x	x	x		x
N587	Structure for Water Control		x	x	x	x		x
	-							
Cost-Share #	Animal Waste Management	Animal Waste Management						
N312	Beef Waste Management System	x	x			x	x	
N312	Dairy Waste Management System	x	x			x	x	
N312	Poultry Waste Management	x	x			x	x	
N312	Swine Waste Management	x	x			x	x	
N316	Incinerator	x	x			x	x	
N317	Composting Facility	x	x			x	x	
Cost-Share #	Nutrient and Pest Management	Nutrient and Pest Management						
N590	Nutrient Management	x	x		x	x	(x)	
N595	Pest Management	x	x					x
Cost-Share #	Sensitive Areas	Sensitive Areas						
C650	Streambank Stabilization		x	x	x	x	x	
DSP-31	Sinkhole Improvement		x	x	x	x	x	x
BDSP-31	Buffer Sinkhole Improvement		x	x	x	x	x	x
N351	Well Decommissioning	x			x	x	x	x

N380	Windbreak/Shelterbelt Establishment	x	x	x	x	x		x
N386	Field Border		x	x	x	x	x	x
N391	Riparian Forest Buffer		x	x	x	x		
N393	Filter Strip		x	x	x	x	x	x
N574	Spring Development	x			x	x	x	
N725	Sinkhole Treatment	x	x	x	x	x	x	x
WQ10	Stream Protection	x	x	x	x	x	x	x
Cost-Share #	Woodland Erosion	Woodland Erosion						
C100	Timber Harvest Plan	x			x	x		
DFR-04	Forest Plantation	x			x	x		
N472	Livestock Exclusion	x			x	x	x	
N655	Restoration of Skid Trails, Logging Roads, Stream Crossings and Log Landings		x	x	x	x		
	Resource Concern and Associated Cost-Share Practices	Avoid	Control	Trap	Sediment	Nutrients	E. coli	Pesticide
Note: The above table is meant to provide examples of the most commonly accepted practices employed in Missouri. It is not meant to preclude other practices that that may be appropriate to specific projects or site conditions.		Practice Mode of Action*			Pollutants Addressed			
*Additional information can be found at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1187023.pdf								
(x) count if management plan is for animal waste								

Table 7.2. Missouri Department of Natural Resources suggested Urban Best Management Practices provided by the Missouri Soil and Water Conservation Program to address impairment issues in Perry County Karst Watershed.

Common Urban Land Management Practices	Practice Mode of Action			Pollutants Addressed			
	Avoid	Control	Trap	Sediment	Nutrients	E. coli	Pesticide
Urban	Urban						
Bioswale		x	x	x	x	x	
Detention basin		x	x	x	x	x	
Fertilizer management	x	x			x		
Enhanced infiltration (soil amendment)	x	x	x	x	x		
Irrigation management	x	x			x	x	x
Low impact landscaping	x			x	x		x
Pest management							x
Porous pavement		x	x		x	x	x
Rain garden		x	x	x	x	x	x
Rain water harvesting	x	x		x	x	x	
Other	Other						
Alum application		x	x		x		
Filter/buffer strip		x	x	x	x	x	x
Grade stabilization structure		x		x			
Grass seeding	x	x		x	x		
Habitat improvement	x	x		x	x	x	
On-site wastewater system upgrade		x			x	x	
Riparian restoration	x	x	x	x	x	x	x
Sediment control basin		x	x	x	x	x	
Sediment removal		x		x	x		
Shoreline stabilization		x		x	x		
Stream bank stabilization		x		x	x	x	

Water diversion	x	x		x	x		
Water retention basin		x	x	x	x	x	x
Well decommissioning	x				x	x	x
Wetland Restoration/Construction		x	x	x	x	x	x
Practice Facilitation	Practice Facilitation						
Conservation consultant							
Crop production deferment	x	x		x	x		x
Common Practices	Avoid	Control	Trap	Sediment	Nutrients	E. coli	Pesticide
	Practice Mode of Action			Pollutants Addressed			
* Note: The above table is meant to provide examples of the most commonly accepted practices employed in Nebraska. It is not meant to preclude other practices that that may be appropriate to specific projects or site conditions.							

Section 8. WATER QUALITY MONITORING

The PCCEEC in conjunction with MDC and MDNR has set forth a monitoring regime for both water quality and macroinvertebrate sampling within PCK. Many of these monitoring regimes will be dependent upon funding from various sources. If funds are not present, the water quality monitoring plan cannot be initiated or completed. The main goals for the PCK watershed are to achieve the aforementioned pollutant concentrations (i.e., sediment, *E. coli*, and surface applied chemicals) compliance to either the MDNR CSR for water quality and drinking water standards or EPA standards. Reducing the pollutants concentrations on these major parameters will ultimately improve the PCK water resources and the habitats that the Grotto Sculpin and other aquatic organisms reside in and promote a sustainable population.

Water Quality Monitoring

Several water quality studies have already been completed (Vandike 1985, Taylor *et al.* 2000, Kraemer, personal communication 2006, MDC 2006, Fox *et al.* 2010) in the PCK watershed. These studies have shown elevated levels of sediment, *E. coli*, and chemical pollutants. These studies have ultimately provided Perry County, state and federal agencies a baseline data set which coupled with future monitoring efforts will begin to detect water quality trends overtime. It will be important to monitor surface streams, springs, resurgence sites, and sub-surface streams for water quality impairments

Proposed monitoring regimes will include sampling at resurgences sites of the major cave systems (Figure 8.1). These will include Blue Springs and Keyhole Springs (Moore Cave System) and Mystery Resurgence (Mystery Cave System) and Thunderhole Resurgence (Running Bull Cave System). At this time, access to Mertz Cave (Crevice Cave System) has been denied. If access is granted in the future, sampling should be conducted at this location. These sites were identified and sampled during the 319 Grant and by Fox *et al.* 2010.

Sampling will consist of using data sondes to collect continuous water quality physical readings as was done previously in the 2008 Section 319 grant. The parameters measured will include dissolved oxygen (mg/L), specific conductivity ($\mu\text{S}/\text{cm}$), pH (units), water temperature ($^{\circ}\text{F}/^{\circ}\text{C}$), and water turbidity (NTU; Table 8.1). Data sondes will be deployed at these locations (anchored and placed in a protective sleeve to ensure viable data and retrieval) and retrieved bi-monthly. Data will be downloaded and corrected for sensor calibrations, sensor drift, sensor failure, and biofouling. Precipitation data will be collected simultaneously as previously done in the 2008 Section 319 grant (see Section 4). In addition, SPMDs and POCISs passive samplers will be deployed from May to July and retrieved as conducted by Fox *et al.* 2010. However, the samplers will be collected and redeployed bi-monthly to reduce biofouling. The samplers will be read by an accredited laboratory.

Grab samples will be collected monthly at the same locations and during time of increased precipitation (spring and fall) will be collected bi-monthly. Grab samples will follow laboratory instructions on handling and collecting and will be delivered to an accredited laboratory within six hours of collection to ensure viable analysis of time sensitive analytes. Samples will be

analyzed for *E. coli*, specific herbicides (i.e., Atrazine), total ammonia nitrogen, TSS, TP, and TN (Table 8.1).

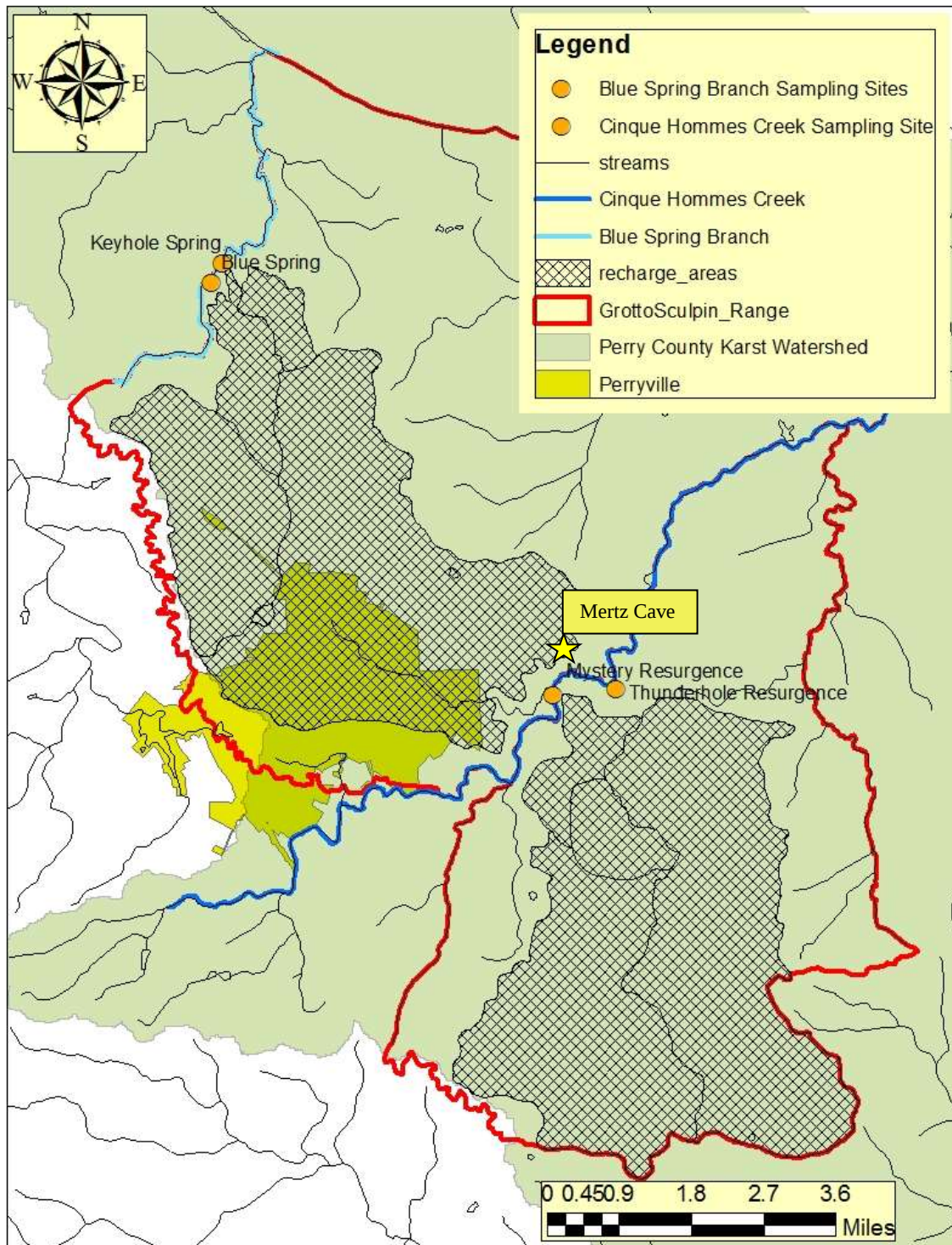


Figure 8.1. Map of proposed sampling locations within the Perry County Karst Watershed. Note the yellow star is an additional sampling location if permission to the site is granted by the landowner.

Table 8.1. Table of proposed water quality parameters to be monitored within the Perry County Karst Watershed.

Proposed key monitoring parameter*	Type of Sample	Monitoring threshold for concern	Source of monitoring threshold	Time of year to sample	Proposed number of samples at base flow	Proposed number of samples for post-rain events	Approximate analytical cost	Rationale for parameter selection
E. coli	Grab	126 colonies/100 ml	DNR Water Quality Standards (WQS)	Year round	1 sample per quarter	1 sample per quarter		E. coli is a human health concern but is included here as an Indicator of habitat degradation for aquatic life; 126 colonies/100 ml was selected because it is the max level allowed for discharges to loosing streams.
Atrazine**	Grab	1 ug/L	EPA OPP	April to July	1 sample per month	opportunistic samples April to July		Most sensitive regulatory level of concern for atrazine. Atrazine is used as a surrogate for other herbicides. Other analytes can be added as needed.
Total Ammonia Nitrogen	Grab	4.1 mg N/l	DNR WQS	Year round	1 sample per quarter	1 sample per quarter		Chronic criteria from WQC for pH 7, 20 C and early lifestage present.
TSS	Grab	20 mg/l	DNR WQS	Year round	1 sample per quarter	1 sample per quarter		Based on weekly average for discharges to loosing streams (p. 5 of WQS)
TP	Grab	0.5 mg/l	DNR WQC	Year round	1 sample per quarter	1 sample per quarter		WQC for Table Rock Lake
TN	Grab	10 mg/L	derived from DNR WQS	Year round	1 sample per quarter	1 sample per quarter		20X TP as speciefied in WQS
Discharge/Stage	Field Measure at all site visits							Each sampling activity should record the discharge (suggest using flowmeter) and stream stage (suggest benchmark location to record water depth).
DO	Field Measure at all site visits	6 mg/L	DNR WQS	Year round	1 sample per quarter	1 sample per quarter		WQC for coldwater streams
pH	Field Measure at all site visits	6-9 units	DNR WQS	Year round	1 sample per quarter	1 sample per quarter		WQC for effluents
Temperature	Field Measure at all site visits	20 C	DNR WQS	Year round	1 sample per quarter	1 sample per quarter		Cold water aquatic life criteria for coldwater
Conductivity	Field Measure at all site visits	500 μ S/cm	EPA	Year round	1 sample per quarter	1 sample per quarter		No DNR criteria, used gernerall literature value for upper part of freshwater range.
Turbidity	Field Measure (if available)			Year round	1 sample per quarter	1 sample per quarter		
SPMD passive sampler	Special sampling	To be determined		May to July	60 day deployment	not applicable		
POCIS passive sampler	Special sampling	To be determined		May to July	60 day deployment	not applicable		
* Prioritized based on results from the 319 monitoring grant								
** Continuing to check to see if other pesticides warrant direct measurement in water samples								

Future efforts should incorporate methods from past studies to ensure accurate comparisons of PCK water quality trends. Seasonal grab samples, water quality logging meters, and stationary samplers might provide the broadest and most effective means to collect multiple types of data. Although water quality samples can be very time sensitive, Stream Team and other community volunteers can be trained to collect some of the rudimentary samples for long term trends throughout PCK. As sample collection becomes more intensified, trained personnel (government or private party) should be involved to ensure the most accurate and representative data are being collected.

Macroinvertebrate Sampling

Surveying the surface and subsurface streams for macroinvertebrate communities is an important indicator of water quality. Historical surveys are now outdated and it will be beneficial to begin a routine monitoring of these waters to procure the most up-to-date species assemblage information. Some species of macroinvertebrates are very sensitive to water chemistry changes and the presence or absence of these sensitive species can give the PCCEEC a view of where to concentrate areas of focus and management. Historically, Stream Teams were used in this area to collect rudimentary water quality information along with macroinvertebrate assemblage information at various locations within the PCK watershed. These historical sites, along with additional sites, should be visited to bring the community to an improved understanding of macroinvertebrate assemblages. Identifying areas where these species indicate poor water quality could be a way to target additional areas with the PCK.

Macroinvertebrate sampling will be conducted using D-frame kick nets at specified locations throughout the PCK watershed. Locations should include the proposed water quality sampling sites as well as additional surface and subsurface streams throughout the PCK watershed. Historical Stream Team sampling sites should also be revisited to identify changes in species assemblage. Sampling should be conducted in a manner at each location to incorporate all existing substrate types (i.e., sand, silt, gravel).

The D-frame kick net will be placed in the stream with its opening facing upstream. A kicking of the substrates in front of the net will dislodge the species allowing them to free flow into the collection cup attached at the cod end of the net. Once the kick is completed, the cup can be removed and species placed in an identification tray to sort through the sediments and detritus pulling out and identifying the macroinvertebrates down to species. Location, date, effort, substrate, water velocity, and species counts will need to be recorded for each resulting kick sample. Physical water quality readings (i.e., temperature, dissolved oxygen, specific conductivity, pH, turbidity) using a data sonde or water quality kit will also need to be collected. A complete species composition and assemblage list will be generated for each sample site along with resulting physical water quality readings and compiled in a central database.

Literature Cited

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APPENDIX A. Steering committee members from 2006 meeting.

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APPENDIX B. Perry County Community Economic and Environment Committee members from 2012 meeting.

Name	Affiliation	email
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Appendix B. Seasonal Summary water quality data collected during the Section 319 grant.

Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Briar Springs (Buehler)	1	Spring	6.9	10.5	8.8	382	722	654	6.49	8.02	7.63	3.52	6.31	5.11	0.076	0.164	0.830
		Summer	3.7	8.5	6.8	339	708	639	6.77	7.94	7.40	3.20	5.80	4.76	0.056	0.361	0.102
		Fall	4.2	8.9	7.2	224	730	647	6.24	7.87	7.37	1.57	6.13	4.36	0.102	0.426	0.159
		Winter	5.9	10.6	9.0	353	703	573	6.75	8.11	7.60	3.05	7.88	5.26	0.082	0.378	0.128
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	1	Spring	12.60	23.44	17.86	1.9	28.4	12.9	0.035	0.286	0.045	6	1660				
		Summer	1.30	21.70	10.93	5.5	39.0	13.4	0.104	0.411	0.149	26	880				
		Fall	4.50	32.12	14.97	2.9	105.5	3.8	0.046	0.077	0.074	87	2400				
		Winter	14.18	24.25	19.40	5.5	42.0	14.0	0.054	0.089	0.066	32	4400				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Blue Spring	2	Spring	8.6	9.8	9.3	318	634	565	6.37	8.09	7.48	3.29	6.61	5.45	0.082	1.990	0.128
		Summer	5.7	9.1	8.1	298	652	523	6.62	7.99	7.76	2.90	6.60	3.43	0.092	0.447	0.141
		Fall	5.6	9.4	8.5	251	637	574	6.18	8.02	7.64	2.90	5.56	3.85	0.121	0.673	0.238
		Winter	8.4	10.7	9.8	394	639	514	6.99	8.17	7.76	5.40	9.70	6.10	0.090	0.560	0.167
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	2	Spring	7.89	23.64	14.00	1.0	2209.1	10.8	0.032	40.095	0.292	34	3100				
		Summer	4.40	21.70	13.98	0.9	54.0	10.2	0.045	0.840	0.132	31	700				
		Fall	10.40	29.17	14.67	2.8	48.0	7.4	0.039	0.320	0.083	22	6560				
		Winter	17.42	26.95	22.99	62.3	110.3	11.3	0.022	0.015	0.037	96	2400				

Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*				
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median		
Huber Branch	3	Spring	8.7	16.0	9.7	366	606	540	6.84	8.84	8.14	2.27	5.45	4.31	0.053	1.490	0.191		
		Summer	5.0	10.4	8.6	471	633	561	7.21	8.22	8.07	4.50	2.69	3.76	0.115	0.328	0.184		
		Fall	6.6	18.3	12.2	370	622	581	7.44	8.69	8.03	0.91	5.29	3.00	0.095	2.054	0.227		
		Winter	12.3	16.7	13.7	137	432	501	7.83	8.91	8.52	2.39	9.94	5.74	0.046	1.600	0.137		
	3		Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*							
			Low	High	Median	Low	High	Median	Low	High	Median	Low	High						
		Spring	5.71	15.56	12.40	0.9	450.7	18.7	--	--	--	120	35200						
		Summer	9.40	20.70	11.38	6.5	104.7	24.5	--	--	--	112	9200						
		Fall	10.43	19.17	14.10	1.9	96.6	6.1	--	--	--	30	7200						
		Winter	11.92	20.98	15.29	2.9	19.5	2.1	--	--	--	46	4280						
		Mertz Cave	4	Spring	8.7	10.0	9.3	311	679	605	6.76	7.85	7.37	2.33	5.55	4.40	0.131	0.417	0.250
				Summer	8.0	9.9	8.7	337	840	539	6.64	7.70	7.45	1.60	3.60	2.16	0.164	0.854	0.288
	Fall			8.6	11.1	9.4	486	644	534	6.92	8.28	7.55	1.82	3.75	2.51	0.157	0.525	0.245	
	Winter			9.0	11.4	9.7	412	661	607	7.29	8.04	7.90	2.79	7.16	3.99	0.128	0.335	0.236	
4			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*							
			Low	High	Median	Low	High	Median	Low	High	Median	Low	High						
	Spring		5.59	21.40	14.15	18.1	394.6	34.5	0.040	8.087	0.295	320	2020						
	Summer		4.40	22.70	9.31	838.4	1984.0	40.0	0.124	1.637	0.410	560	6800						
	Fall		6.83	65.70	16.19	14.8	59.4	24.0	0.063	0.330	0.110	20	3640						
	Winter		14.98	26.59	20.87	14.8	47.4	33.8	0.067	0.089	0.078	96	5200						
			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)		TP (mg/L)*					
			Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median		

Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
CHC* Below WWTP	5	Spring	7.5	11.0	8.1	254	667	514	6.61	8.07	7.81	0.87	3.15	2.50	0.223	0.887	0.617
		Summer	5.3	7.2	6.1	772	5668	572	6.13	7.81	7.75	0.15	5.97	4.16	0.990	1.490	1.199
		Fall	7.0	12.1	10.7	759	5481	654	7.23	8.33	7.80	1.94	7.68	3.57	0.338	1.710	1.115
		Winter	10.1	15.8	12.3	298	622	473	6.69	8.57	7.78	1.84	4.22	2.83	0.290	1.010	0.585
	Site	Season	Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
			Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	5	Spring	7.19	39.94	19.96	71.8	195.1	12.1	--	--	--	2	4000				
		Summer	11.28	108.70	44.83	24.2	85.0	6.5	--	--	--	640	6000				
		Fall	15.08	91.70	35.99	17.7	71.5	3.8	--	--	--	2	940				
		Winter	15.78	44.99	34.97	3.7	27.2	9.0	--	--	--	2	9600				
Parameter	Sample Site	Season	DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Low			High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	
Mystery Resurgence	6	Spring	9.5	8.1	9.1	188	563	519	6.57	7.71	7.56	1.10	3.63	3.21	0.102	0.791	0.235
		Summer	7.6	8.8	8.4	328	584	553	6.37	7.58	7.38	2.00	3.20	2.94	0.099	0.364	0.184
		Fall	6.8	11.1	8.2	235	527	441	6.48	7.92	7.32	1.48	3.39	1.87	0.125	0.768	0.407
		Winter	8.9	10.9	9.9	245	589	491	6.93	7.90	7.61	2.10	5.49	4.01	0.092	0.667	0.242
	Site	Season	Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
			Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	6	Spring	3.19	13.64	10.12	15.7	230.6	29.6	0.050	3.323	0.301	--	--				
		Summer	6.98	11.70	8.33	6.4	28.0	17.8	0.085	6.164	0.285	--	--				
		Fall	6.73	13.50	8.98	14.9	667.0	29.0	0.054	0.320	0.126	--	--				
		Winter	6.71	17.89	13.18	14.1	148.9	34.4	0.038	0.063	0.045	--	--				
Parameter	Sample Site	Season	DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Low			High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	

CHC* at Hwy 61	7	Spring	9.3	12.9	10.3	217	445	384	6.47	8.40	8.11	0.23	0.63	0.43	0.003	0.088	0.035	
		Summer	6.7	9.7	9.2	322	548	403	6.27	8.01	7.91	0.62	0.27	0.45	0.050	0.673	0.069	
		Fall	9.7	18.3	10.7	338	461	422	6.02	8.61	7.84	0.09	3.08	0.32	0.013	0.135	0.079	
		Winter	11.9	17.0	13.5	251	454	381	7.55	8.76	7.82	0.38	0.99	0.75	0.007	0.128	0.045	
	7	Site	Season	Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
				Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
		Spring	2.57	11.76	8.70	25.9	0.9	6.5	--	--	--	56	1900					
		Summer	1.61	14.70	6.24	1.9	851.9	3.7	--	--	--	48	16800					
		Fall	7.48	27.96	14.97	0.9	9.3	3.5	--	--	--	36	7200					
	Winter	9.02	20.59	14.47	2.8	7.4	6.0	--	--	--								
Parameter	Sample Site	Site	Season	DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Low				High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	

Thunderhole Resurgence	8	Spring	9.3	10.8	9.8	188	618	546	7.30	8.07	7.76	3.35	4.81	4.20	0.105	0.752	0.148	
		Summer	8.8	9.9	9.4	378	647	551	6.88	7.70	7.52	3.10	4.80	4.30	0.046	0.351	0.201	
		Fall	8.8	12.0	9.9	195	601	530	6.63	8.44	7.09	2.42	7.63	3.36	0.197	0.728	0.293	
		Winter	9.7	12.0	10.0	271	580	529	7.30	8.07	7.76	3.21	7.06	4.96	0.105	0.050	0.175	
	8	Site	Season	Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
				Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
		Spring	3.68	12.76	11.69	0.9	217.2	10.2	0.041	2.762	0.230	35	5200					
		Summer	5.40	12.70	7.88	0.9	15.0	3.9	0.120	3.257	0.808	2	304					
		Fall	5.68	23.57	10.45	0.0	71.8	9.1	0.064	0.790	0.118	2	260					
	Winter	7.57	18.48	13.62	49.7	112.2	13.2	0.055	0.065	0.060	110	7760						
Parameter	Sample Site	Site	Season	DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Low				High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	

Cedar Springs	9	Spring	7.9	11.6	8.5	198	575	455	7.02	8.26	7.46	1.24	3.66	2.75	0.089	0.620	0.296
		Summer	5.7	11.4	5.7	380	508	444	7.30	7.40	7.36	3.08	3.10	3.09	0.013	0.223	0.118

		Fall	1.2	9.2	5.9	394	538	484	6.74	7.56	7.16	1.86	2.71	2.22	0.260	0.447	0.315
		Winter	7.5	12.0	10.4	279	530	484	7.39	7.88	7.74	1.70	5.21	3.29	0.141	0.351	0.217
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	9	Spring	2.97	9.46	5.61	11.1	237.5	38.4	0.062	40.544	1.790	24	3000				
		Summer	3.60	7.60	5.64	19.6	19.7	19.6	0.511	8.202	0.804	56	72				
		Fall	7.53	13.27	7.77	6.4	26.4	21.0	0.083	0.800	0.132	12	258				
		Winter	4.63	14.49	5.61	7.4	48.0	25.4	0.086	0.089	0.087	62	350				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Dry Fork Creek	10	Spring	6.8	11.1	0.6	353	579	552	7.40	8.28	7.87	0.72	2.22	1.75	0.026	0.939	0.104
		Summer	1.4	7.0	6.0	405	516	503	7.04	7.86	7.60	0.09	1.60	1.30	0.059	0.204	0.089
		Fall	2.7	14.3	8.5	368	574	506	6.79	8.72	7.30	0.13	3.04	1.60	0.029	0.372	0.210
		Winter	8.4	15.1	12.3	459	588	482	7.10	8.43	7.90	0.58	2.86	2.23	0.027	0.220	0.087
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	10	Spring	3.90	13.06	9.16	1.9	21.3	4.2	--	--	--	96	32000				
		Summer	1.97	15.70	9.18	4.6	11.9	6.9	--	--	--	86	4000				
		Fall	7.08	13.87	11.40	2.7	29.1	4.6	--	--	--	12	4160				
		Winter	9.41	15.89	12.07	1.9	21.3	4.2	--	--	--	22	1680				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Mystery Spring (entrance)	11	Spring	7.1	10.3	8.8	135	564	183	6.18	7.98	7.71	0.43	2.42	1.93	0.181	1.330	0.539
		Summer	3.4	8.5	7.7	301	688	538	6.43	7.93	7.60	0.34	1.80	1.10	0.233	1.010	0.312
		Fall	6.1	11.9	8.9	236	691	464	6.28	8.28	7.46	0.33	2.43	0.59	0.243	1.930	0.478
		Winter	9.5	11.1	10.3	151	540	476	7.12	8.06	7.84	0.93	4.06	2.36	0.145	1.350	0.396

			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
11		Spring	3.57	20.04	9.84	5.3	190.0	47.0	--	--	--	400	17600				
		Summer	0.67	20.70	10.38	6.6	827.3	50.6	--	--	--	720	23200				
		Fall	1.59	27.30	13.82	8.1	154.2	52.1	--	--	--	29	10640				
		Winter	4.55	23.29	18.02	17.0	112.1	25.3	--	--	--	240	6000				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Omete Creek	12	Spring	8.0	13.2	9.1	276	652	595	5.48	8.52	7.90	1.70	4.41	2.80	0.023	0.880	0.089
		Summer	4.0	9.2	7.4	416	549	507	6.43	7.86	7.70	1.70	3.40	2.80	0.020	0.256	0.061
		Fall	5.9	15.6	11.3	366	594	525	5.93	8.74	7.59	1.75	4.83	2.15	0.072	0.433	0.217
		Winter	10.8	14.5	13.4	484	627	553	7.80	9.13	8.12	2.42	6.12	4.16	0.040	0.243	0.120
				Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*				
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	12	Spring	4.97	15.54	10.94	2.8	1140.3	12.2	0.066	6.321	0.822	420	38400				
		Summer	7.40	19.70	14.07	4.8	156.1	13.9	0.135	0.927	0.312	60	1360				
		Fall	1.77	16.07	13.47	0.7	48.7	12.4	0.097	0.160	0.142	4	6400				
		Winter	11.82	18.99	16.07	3.7	18.1	10.9	0.054	0.099	0.074	337	2030				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Scholl Spring	13	Spring	9.4	10.5	10.1	312	827	759	6.19	8.60	7.90	0.51	1.45	1.01	0.013	0.322	0.157
		Summer	8.5	10.1	9.7	569	942	767	6.98	7.99	7.71	0.98	1.20	1.11	0.030	0.204	0.066
		Fall	9.6	12.3	10.1	315	918	765	6.59	8.32	7.61	0.75	4.21	1.01	0.082	0.532	0.205
		Winter	9.9	11.7	10.6	331	838	687	7.20	8.24	7.65	0.68	1.70	0.96	0.023	0.480	0.131
				Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*				

	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	13	Spring	10.60	40.59	22.50	3.1	72.3	19.7	--	--	--	52	14400				
		Summer	10.95	62.70	45.40	10.2	166.0	17.0	--	--	--	42	320				
		Fall	4.70	74.77	15.33	6.5	49.5	22.4	--	--	--	16	6600				
		Winter	10.48	55.09	31.65	10.4	76.0	31.4	--	--	--	8	33600				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Brazeau Creek	14	Spring	8.4	13.4	9.4	242	791	535	6.73	8.48	7.89	1.65	3.80	3.18	0.023	1.040	0.078
		Summer	5.2	8.7	7.6	447	529	482	6.74	8.27	7.89	2.21	3.60	3.01	0.007	0.148	0.066
		Fall	6.5	16.1	11.2	417	555	521	6.40	8.69	7.63	0.56	3.55	2.19	0.042	0.519	0.225
		Winter	11.0	16.3	14.2	433	569	506	7.55	8.63	8.34	2.23	4.89	3.86	0.026	0.214	0.118
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	14	Spring	4.34	17.14	12.95	4.6	309.0	7.5	0.037	13.540	0.300	16	15200				
		Summer	9.67	18.70	14.18	7.5	34.0	15.7	0.116	0.380	0.156	90	560				
		Fall	0.70	21.97	15.54	2.8	108.5	11.1	0.071	0.280	0.125	44	2200				
		Winter	13.00	19.10	18.15	2.7	16.0	6.7	0.052	0.116	0.075	162	2000				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Indian Creek	15	Spring	6.2	11.0	7.2	194	551	514	6.34	7.83	7.50	1.31	2.37	1.95	0.013	0.686	0.045
		Summer	2.6	9.2	5.6	404	484	443	6.40	8.13	7.40	0.49	2.00	1.50	0.023	0.325	0.062
		Fall	3.8	14.4	9.6	374	541	470	5.90	8.38	7.14	0.88	2.70	1.32	0.135	0.345	0.140
		Winter	7.7	13.8	12.2	417	565	455	7.44	8.66	7.60	1.77	2.93	2.47	0.004	0.220	0.073
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	15	Spring	2.50	77.60	8.16	0.8	76.9	4.6	--	--	--	162	56800				

		Summer	7.40	16.70	12.15	0.5	69.5	9.6	--	--	--	120	2340				
		Fall	1.08	13.07	10.47	0.9	66.9	3.7	--	--	--	74	2200				
		Winter	8.62	13.05	11.88	2.8	20.5	6.5	--	--	--	8	3200				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Apple Creek Shrine (Shrine Karst Window)	16	Spring	7.3	9.7	9.4	152	562	513	6.34	7.71	7.41	0.82	2.77	5.59	0.030	1.100	0.092
		Summer	6.7	9.1	8.0	312	505	449	6.50	7.55	7.08	0.17	3.30	20.70	0.036	0.171	0.140
		Fall	5.5	11.6	7.9	224	502	388	5.90	7.62	6.63	1.10	2.19	1.40	0.075	0.456	0.246
		Winter	8.9	11.5	9.9	304	258	496	6.44	7.69	7.03	2.38	11.80	2.70	0.040	0.407	0.196
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
			Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	16	Spring	1.33	7.52	5.06	644.9	840.0	10.2	0.036	5.402	0.333	40	7200				
		Summer	0.63	15.61	2.49	35.9	108.8	6.4	0.130	1.193	0.226	12	352				
		Fall	2.31	5.39	3.20	49.3	173.6	20.2	0.051	0.270	0.078	2	8800				
		Winter	4.48	38.85	6.33	36.9	104.0	8.4	0.049	0.054	0.052	22	3800				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*		
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
CHC* at Hwy 55	17	Spring	9.2	14.0	11.1	195	414	356	7.01	8.74	8.30	0.03	0.52	0.14	0.004	0.135	0.006
		Summer	6.7	12.9	11.5	244	476	408	7.69	8.44	8.25	0.14	0.61	0.20	0.650	0.010	0.013
		Fall	7.7	17.1	14.7	279	500	430	6.58	8.84	8.56	0.28	1.14	0.21	0.023	1.077	0.030
		Winter	12.1	16.6	13.9	216	412	321	7.38	9.01	8.58	0.17	0.91	0.35	0.019	0.095	0.028
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
			Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	17	Spring	3.76	7.31	6.20	0.0	23.9	0.9	--	--	--	2	4000				
Summer		2.90	9.70	5.55	0.9	103.6	1.9	--	--	--	640	6000					
Fall		3.28	13.10	9.39	0.9	19.8	2.8	--	--	--	2	880					

		Winter	5.49	12.48	8.77	1.0	7.0	2.4	--	--	--	2	9600					
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*			
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	
SFSC*	18	Spring	8.7	12.8	10.2	152	371	286	6.58	8.44	7.78	0.04	0.31	0.07	0.006	0.056	0.003	
		Summer	6.7	8.9	8.0	244	394	375	6.96	8.07	7.95	0.02	0.05	0.02	0.010	0.010	--	
		Fall	8.2	15.2	12.3	235	420	334	6.19	8.67	8.17	0.07	0.49	0.13	0.026	0.151	--	
		Winter	11.2	13.9	12.7	186	389	283	7.40	8.97	8.03	0.03	0.74	0.40	0.009	0.036	0.015	
				Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
				Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
		18	Spring	0.22	2.23	0.81	0.1	3.8	1.5	0.011	0.229	0.053	2	112				
			Summer	1.20	1.30	--	0.9	23.1	2.9	0.014	40.868	0.043	2	239				
			Fall	0.76	2.01	--	0.9	8.2	0.9	0.024	0.077	0.051	2	250				
	Winter		0.36	27.85	2.30	0.9	12.7	1.9	0.014	0.017	0.015	2	240					
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*			
Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	
Keyhole Spring ***	19	Spring	9.2	9.6	9.4	528	588	558	6.84	7.70	7.67	6.10	6.12	6.10	0.059	0.181	0.086	
		Summer	7.6	9.4	9.1	424	585	580	6.26	7.53	7.14	3.21	5.23	4.16	92.000	0.181	0.131	
		Fall	8.5	9.0	8.9	446	648	565	6.46	6.76	6.61	4.22	4.90	4.43	0.131	0.204	0.164	
		Winter	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
				Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
				Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
		19	Spring	18.49	20.69	19.59	36.1	56.7	11.2	0.050	16.932	0.362	2	104				
			Summer	10.38	16.17	10.45	7.7	24.8	22.6	0.065	35.815	0.300	54	280				
			Fall	9.63	30.83	15.78	4.8	9.3	6.4	0.084	0.400	0.218	16	447				
	Winter		--	--	--	--	--	--	--	0.033	0.160	0.055	--	--				
Parameter			DO (mg/L)			Spec. Conductance			pH			Nitrate (mg/L)			TP (mg/L)*			

Sample Site	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
Ball Mill Spring ***	20	Spring	7.8	9.2	8.6	637	655	644	6.88	7.51	7.26	4.67	6.19	5.56	0.102	0.187	0.138
		Summer	3.7	7.3	6.0	273	689	667	6.26	6.86	6.67	2.16	5.56	4.95	0.148	0.086	0.195
		Fall	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Winter	8.4	854.0	8.5	611	619	615	7.20	7.70	7.45	4.41	4.83	4.59	0.138	0.151	0.151
			Chloride (mg/L)			TSS (mg/L)			Atrazine (µg/L)			E. coli (colonies/100ml)*					
	Site	Season	Low	High	Median	Low	High	Median	Low	High	Median	Low	High				
	20	Spring	--	--	--	0.9	12.5	5.1	0.017	30.306	0.093	--	--				
		Summer	--	--	--	7.4	102.5	25.1	0.059	0.384	0.091	--	--				
		Fall	--	--	--	--	--	--	0.026	0.084	0.051	--	--				
		Winter	--	--	--	11.1	12.4	12.4	0.024	0.096	0.055	--	--				

*TP denotes total phosphorus; Specific Cond denotes specific conductivity, and TSS denotes total suspended solids

**CHC denotes Cinque Hommes Creek; SFSC denotes South Fork Saline Creek

*** These two sites were added later so data represented is from 2010 and 2011

Appendix C. Accomplishments by the Perry County Community Economic and Environment Committee from 2012 to present.